INSTITUTO FIGUEROLA
DE HISTORIA Y CIENCIAS SOCIALES

Growth, War, and Pandemics: Europe in the Very Long-run

Leandro Prados de la Escosura, and Carlos Vladimir Rodríguez-Caballero

Working Papers in Economic History

2020-07

ISSN: 2341-2542

uc3m | Universidad Carlos III de Madrid

Serie disponible en http://hdl.handle.net/10016/19600

Web: http://portal.uc3m.es/portal/page/portal/instituto_figuerola

Correo electrónico: figuerola@uc3m.es

Growth, War, and Pandemics: Europe in the Very Long-run

Leandro Prados de la Escosura*, and Carlos Vladimir Rodríguez-Caballero†

ABSTRACT

This paper contributes to the debate on the origins of modern economic growth in Europe from a very long run perspective using econometric techniques that allow for a long-range dependence approach. Different regimes, defined by endogenously estimated structural shocks, coincided with episodes of pandemics and war. The most persistent shocks occurred at the time of the Black Death and the twentieth century's world wars. Our findings confirm that the Black Death often resulted in higher income levels, but reject the view of a uniform long-term response to the Plague while evidence a negative reaction in non-Malthusian economies. Positive trend growth in output per head and population took place in the North Sea Area (Britain and the Low Countries) since the Plague. A gap between the North Sea Area and the rest of Europe, the *Little Divergence*, emerged between the early seventeenth century and the Napoleonic Wars lending support to Broadberry-van Zanden's interpretation.

JEL Codes: E01, N10, N30, N40, O10, O47

Keywords: Long-run Growth, *Little Divergence,* War, Pandemics, Malthusian

* Universidad Carlos III and CEPR. leandro.prados.delaescosura@uc3m.es
† Dept of Statistics, ITAM, Mexico, and CREATES, Aarhus University. vladimir.rodriguez@itam.mx

I. Introduction

When does modern economic growth, namely, a sustained increase in output per head or worked hour, accompanied by population expansion (Kuznets, 1966), emerge? Economists have tried to explain the transition from a society in which average income is stagnant to another in which its levels increase irreversibly over time (Hansen and Prescott, 2002). This approach assumes no sustained improvement in material living standards before 1820, when the First Industrial Revolution spread over Western Europe. The Unified Growth Theory, that models the transition from a Malthusian economy -in which land is in fixed supply, capital accumulation and technological change proceed very slowly, and any increase in output per head triggers a direct response of population- to a modern economy, provides a more nuanced approach that allows for mild per capita income growth in a late stage (Galor and Weil, 2000; Galor, 2011).

Does historical evidence support such a dichotomy of stagnation or growth? A strict Malthusian depiction of the pre-Industrial Revolution era, with no long-term gains in living standards, has been supported by economic historians (cf. Clark, 2007). New quantitative research on preindustrial European economies has found, however, episodes of sustained growth that, although often reverted, led to higher levels of income per head (van Zanden and van Leewen, 2012; Broadberry et al., 2015; Krantz, 2019; Prados de la Escosura et al., 2020). Would it be preferable, then, to describe European preindustrial economic performance, rather than as Malthusian, as a series of growth reversal episodes, in which increases in average incomes are largely cancelled out by subsequent episodes of decline (Cf. Broadberry and Wallis (2017)? Or should these 'efflorescence' (Goldstone, 2002) or 'growth recurring' (Jones, 1988) episodes be better depicted as a weak version of the Malthusian model?

The new quantitative evidence provides the grounds for a new interpretation that claims that the sustained economic growth in Western Europe since 1820 sinks its roots in the centuries between the Black Death and the Napoleonic Wars (Broadberry, 2013; de Pleijt and van Zanden, 2019). This experience would have been restricted to some regions in north-western Europe, including Flanders, Holland, England and Wales, and Scotland, that became increasingly integrated into an economic unit, the North Sea Area. In the North Sea Area a distinctive reaction to the Black Death resulted in higher permanent income levels. Moreover, the North Sea Area exhibited over time differences in terms of demographic patterns (the European Marriage Pattern), human capital formation, institutions (commodity and factor markets, Parliaments), and international trade (Acemoglu et al., 2005; Broadberry, 2013; de Moor and van Zanden, 2010; de Pleijt and van Zanden, 2016, 2019; van Zanden et al., 2012). Such a transformation, eventually facilitated the launching of the Industrial Revolution.

As a consequence of this successful growth process, a growing gap in terms of income per head and structural change emerged between the North Sea Area and the rest of continental Europe, the so-called *Little Divergence*. The *Little Divergence* also carried with it a reversal of fortunes as Britain and the Netherlands exchanged positions with earlier leading economies, such as Italy and Spain (Fouquet and Broadberry, 2015; Henriques and Palma, 2019).

The emergence of the *Little Divergence* has implications for the global debate on the origins of the *Great Divergence*, namely, the increasing gap in average incomes between Europe and Asia. The early rise of the North Sea Area implies that the roots of the *Great Divergence* go back to the Black Death aftermath and the European overseas expansion. Such an interpretation, in line with the view of an earlier European primacy supported by Braudel (1973), Jones (1981), or Maddison (2007), challenges the interpretation by California School - including, among others, Frank (1998), Pomeranz (2000), and Goldstone (2002, 2019)-, which dates the beginnings of the *Great Divergence* at the onset of industrialization in north-western Europe.

In a nutshell, the issue at stake is whether modern economic growth was initiated in north-western Europe before the late eighteenth century. While in Broadberry-van Zanden's narrative, slow but sustained per capita income growth since 1348, accompanied by structural transformation, made the North Sea Area to forge ahead the rest of Europe and Asia, according to the California School, continuous gains in average incomes along population expansion were absent in Europe until as late as 1750. The episodes of growth observed in north-western Europe were not significantly different from previous 'efflorescence' experiences, just isolated and short phenomena that, when exhausted, led to another Malthusian equilibrium (Goldstone, 2002). Thus, no thriving North Sea Area would have existed before 1750. The Netherlands stagnated after its Golden Age and Britain's per capita income only improved in the late 14th and 17th centuries at times of population decline or stagnation. Furthermore, the income levels achieved in Holland or England before 1800 were not different from those reached in Renaissance Italy or Song China (Goldstone, 2019).

The relevance of the new evidence and interpretation for European and global economic history is clear. However, the debate has not been accompanied by formal statistical procedures and testing. Historical analysis of European long run growth and the *Little Divergence* has been mainly impressionistic so far. This implies that the current narrative on growth and divergence can be easily challenged.

The availability of GDP per head series for Western European countries since the late middle ages provides a unique opportunity to investigate growth in the very long run. The Black Death, the beginning of the overseas expansion in 1500, and the Industrial Revolution are considered events that contributed to growth and divergence across Europe (Pamuk, 2007; Broadberry, 2013; de Pleijt and van Zanden, 2016, 2019; Jedwab et al. 2019). Wars have been also associated to changes in growth and leadership within Europe (Voigtländer and Voth, 2013a; O'Brien, 2018). Can the impact on growth and divergence of such events be assessed more rigorously with the help of modern quantitative techniques?

Crafts and Mills (2017) employed time-series analysis to investigate whether British long-run economic growth followed a segmented trend-stationary process, in which shocks have transitory effects and the series have mean reversion, that is, series reverts to the trend line almost immediately after the occurrence of the shock, or a difference stationary process, in which shocks have permanent effects on the series, and also, whether different data generating processes apply before and after the Industrial Revolution. A cubic segmented trend stationary model provides, according to Crafts and Mills, the best depiction of Britain's performance over six centuries. Their main finding is that zero trend growth prior to 1660 was followed by accelerations before and after the Industrial Revolution. This implies anticipating the onset of modern economic growth by nearly a century with respect to Goldstone's (2019) assessment. Moreover, their results lend support to Galor's (2011) two-stage growth acceleration and to Voigtländer and Voth's (2013b) depiction of the Black Death as an exogenous shock that allowed higher permanent income levels.

This paper contributes to the literature on long run growth and the *Little Divergence* in Europe by using time-series analysis but, rather than following Crafts and Mills (2017), we have opted for a long-range dependence approach (also known as long memory or fractional time series analysis) in which persistence levels of different shocks may vary. In this sense, we relax the view that shocks may vanish in the short term, or on the contrary, they may be permanent and, consequently, never die out. Also, following Crafts and Mills (2017), we investigate whether some historical events provoke structural breaks in the trend of the series, and then define regimes with different levels of persistence. Our results show that regimes, defined by the endogenously estimated structural breaks at roughly similar dates for practically all countries, often coincide with episodes of pandemics and war. Moreover, we establish the persistence of the different shocks showing that the most persistent ones occurred at the time of the Black Death and the twentieth century's world wars.

Secondly, our findings confirm that the Black Death often resulted in higher income levels but reject the view of a uniform positive long-term response to the Plague. The higher income levels achieved were partly reverted (Italy), or became permanent (Britain, France, the Netherlands). Moreover, frontier economies reacted negatively to the Black Death and average income levels experienced a long run decline (Spain and Sweden).

Thirdly, we have investigated the extent to which countries in Europe behaved in a conventional Malthusian fashion since the Black Death. While inversely related tendencies in average incomes and population confirm the Malthusian pattern in most cases, the time frame is different across countries. Moreover, we also found population and output per head evolving alongside, at odds with the Malthusian paradigm, in the case of Spain.

Fourthly, the paper contributes to the debate about the origins of modern economic growth in Europe. Unlike most European countries, trend growth in per capita income occurred in Britain since the early 1600s, and represented a sustained process in the Netherlands since Black Death. Furthermore, neither the Low Countries nor Britain did suffer growth reversals (that is, phases of negative trend growth). If we focus on the North Sea Area as a whole, per capita income gains, along population expansion, took place gradually after the Plague. Furthermore, our results confirm the existence of *Little Divergence* that became a generalised phenomenon from the seventeenth century onwards. Thus, our results lend support to Broadberry-van Zanden's interpretation.

The paper is organized as follows. First, the long memory econometric approach is discussed and the available data presented. Then, we investigate the existence of structural breaks, the regimes they defined, and their persistence, highlighting analogies and differences across countries. Next, we look for Malthusian patterns in Europe and the onset of modern economic growth. Finally, we assess convergence and divergence trends with respect to the North Sea Area.

2. Econometric tools

2. 1 The long memory approach

One of the main characteristics of the dynamics of many economic time series is persistence. Economists and policy makers study the concept of persistence because of its key role in determining how some economic variables respond to different shocks over time. Persistence measures the speed at which some shocks to the particular economic variable die out. Traditionally, persistence has been located in two opposite borders. On the one hand, when a variable is stationary (weakly dependent or I(0) process), the time series go back to the original trend after a shock occurs. On the other, when the time series is non-stationary, particularly when the time series contain a unit root, its random behaviour makes the shock never to die out. These type of time series are also often called difference-stationary processes because a difference is necessary to transform the variable to be stationary, denoted as I(1) process.

A branch in econometrics has studied the concept of long memory intrinsically related to the measure of the persistence. The paradigm of long-range dependence seems to be appropriate to describe the high degree of persistence that many economic time series exhibit in the form of a long lasting effects of unanticipated shocks. An important feature of long memory models is that, even if they are stationary, will predict higher levels of persistence that cannot be captured by traditional stationary ARMA models. In this sense, long memory means that a significant dependence exists between observations very widely separated in time, where the effects caused by some specific shocks decay much more slower compared with ARMA models.[1]

Visually, an idea of long memory in the covariance sense is given by the behaviour of the autocorrelation function for long lags of our time series, that is, GDP per head for a sample of European countries over the last seven centuries (see Figure 1).

As we detail in Appendix A (equation A.1), the fractional memory parameter d plays a key role in the definition of long memory, because it governs the long-run dynamic of the process as a measure of persistence. That is, the higher value on d, the longer lasting effects of shocks on the y_t process.

[1] Long memory has been studied in many macroeconomic variables, Gil-Alana and Robinson (1997) analyse the persistence level of many macro variables, Gil-Alana (2004) measures persistence for the growth rates of real GDP series across various countries, while inflation rates has often been studied, see Baillie et al. (1996), and Canarella and Miller (2016), for instance. Readers are referred to Appendix A.1 for a brief technical section regarding long memory literature.

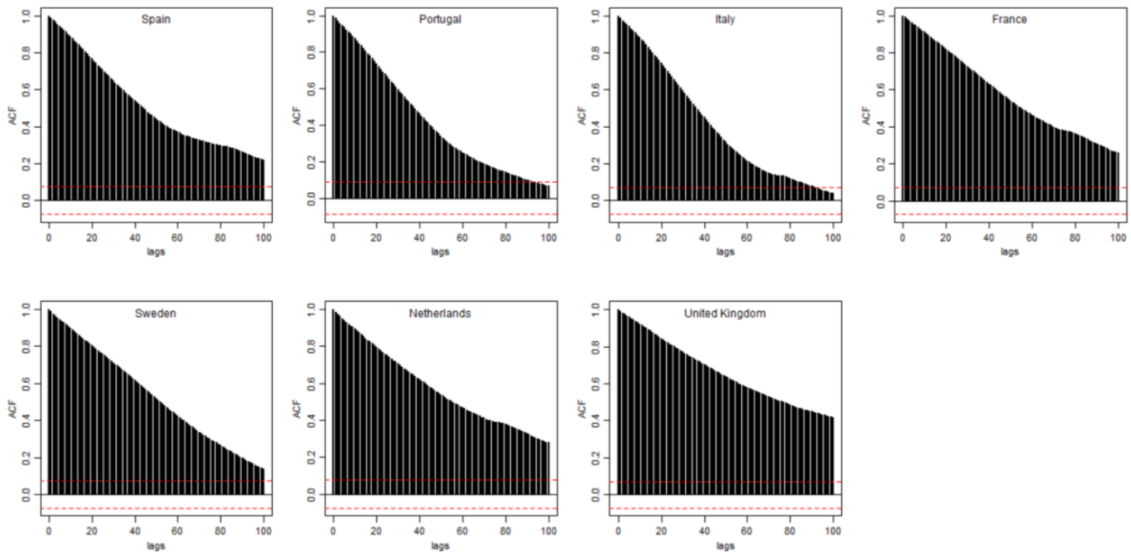

Figure 1. Autocorrelation Functions of GDP per Head (logs) for the Countries' Sample

We extent the possibilities that d may take any real number, then our analysis is not restricted to the cases with $d = 0$ and $d = 1$. Note the following implications of the parameter d:

An I(0) process, i.e. a process with $d = 0$, displays short memory, and implies that any shock that affects the series only has repercussion in the short-term because its impact will completely vanish in the long run.

- The process will be stationary as long as $d < 0.5$.
- The process will be non-stationary for $d \geq 0.5$, and possesses an infinite variance.
- The process will display long memory for $0 < d < 1$.
- The process will revert to its mean as long as $d < 1$. This implies that any shock in the process has nonpermanent effect on the series, that is, these shocks are transitory.
- Processes with $d = 1$ (and superior integer orders) are named ARIMA model and are frequently used after taking d differences. In particular, a process with $d = 1$ implies that past innovations in ϵ_t have permanent effects on y_t.

In order to estimate this memory parameter, we use two methods. First, the Two-Step Exact Local Whittle (2ELW) estimator proposed by Shimotsu (2010) that is very useful for economic data because it accommodates unknown means and polynomial time trends. Second, as a robustness check, we also use the fully extended local Whittle (FELW) estimator proposed by Abadir et al. (2007) that covers consistently a long range of values with $d \in \left(-\frac{3}{2}, \infty\right)$. In the FELW procedure, the observable process may be driven by an additional time trend that does not have to be accounted for in contrast with the 2ELW procedure.

Both estimators are consistent for $d \in \left(-\frac{1}{2}, \frac{1}{2}\right) \cup \left(\frac{1}{2}, \frac{3}{2}\right)$ and have the following limiting result

$$\sqrt{m}\left(\hat{d}_m - d\right) \xrightarrow{d} N\left(0, \frac{1}{4}\right) \qquad \text{as } T \to \infty, \tag{1}$$

where m is the bandwidth, $m \in \{T^{0.60}, T^{0.65}, T^{0.70}\}$. We use $m = T^{0.70}$ as the benchmark bandwidth to avoid higher-frequency contamination, while the remaining are useful for robustness checks.

2.2 Test for structural breaks

In this paper, we make no assumptions about the existence or location of breaks. We highlight that one of our main goals is to estimate when a particular event really exerted its effects. Each pair of adjacent breaks define a period known as 'regime', which may not necessarily coincide with those defined by the exogenous breaks sometimes used in historical analysis.

The transcendence of structural breaks has grown with the advent of the unit root literature mainly as a consequence of Perron's (1989) influential paper. The relevant task is to distinguish between trend-stationary and difference-stationary processes when the true process is subject to structural changes.[2] Nevertheless, the methodology adopted originally by Perron (1989, 1990) has been criticized because the breaks are treated as known. Therefore, subsequent studies have used automatic or recursive tests to endogenize the break point on the grounds different data generating processes can be found by relaxing the exogeneity assumption of the breakpoint (Cf. Christiano, 1992; Zivot and Andrews, 1992; and Perron, 1997).

We relax Crafts and Mills's (2017) exogenous breaks approach here, and opt for a data-dependent algorithm to estimate the date of breaks. In our view, one never selects blindly a date to test for a break without prior information about the data. Then, even

[2] Even before this literature exploded after Perron's influential papers, we can track hundreds of different applications, see Hackl and Westlund (1989) for a very extensive list of references. By the end of the 1980s and mostly during 1990s, structural breaks pervaded many different branches of the econometric literature. These include models with general stationary short-memory regressors and errors, trends with integrated and/or stationary errors, models with trending variables and possible unit roots, cointegrated models and long memory processes, multivariate systems of equations, among many others, see Perron (2006) and Casini and Perron (2018) for comprehensive updated reviews. See Mills (2016) to review the approach adopted in cliometrics.

when a break time based on historical events is assumed exogenously, a (hidden) data analysis is previously performed.[3]

We use the Bai and Perron (1998, 2003a,b) (henceforth BP) structural break method to estimate both the number and date of structural breaks in GDP per head and divergence time series of the European countries' sample in a linear regression framework (a methodological explanation is offered in Appendix A, section A.2).

In our study, we are interested on testing and dating whether the linear trend of y_t changes over time. Then, we focus on the following simple specification,

$$y_t = \beta_{0,j} + \beta_{1,j}\, t + u_t, \qquad t = T_{j-1}, \dots, T_j. \qquad (2)$$

for $j = 1, \dots, m+1$, where y_t is the GDP per head or divergence indices of the respective country analysed, $\beta_{0,j}$ and $\beta_{1,j}$ $(j = 1, \dots, m+1)$ are the parameters to be estimated corresponding to the intercept and the slope of the linear trend fitted to the variable in the jth regime.

We determine the number of breaks and their location employing the $\mathrm{SupF}(\ell + 1|\ell)$ test described in the BP methodology, which sequentially tests the null hypothesis of ℓ breaks against the alternative of $\ell + 1$ breaks. We calibrate the trimming parameter, $h \in [0.08, 0.12]$, in each separate case. Finally, we estimate the fractional memory d by 2ELW and FELW methods explained before for each one of the regimes previously estimated.

3. Data

We have focus on a sample of seven European countries for which long series for real output and population are available. For all countries, but Spain, the GDP series from Conference Board (2019) and the Maddison Project Database (2013) have been used for the most recent period. The construction of homogeneous series for each country has been as follows.

Italy. Conference Board (2019) series were spliced with Bafiggi's (2012) for 1861-2010 estimates and, then, projected backwards with Malanima's (2011) estimates for North and Central Italy back to 1310, assuming the rest of the country evolved alongside.

[3] It is true that sometimes, we can have prior knowledge about the occurrence of a break, for instance, the Black Death; however, there may be some periods when it is really cumbersome to distinguish breaks, for example, between the Great Depression and the start of World War II. In such cases, one certainly needs to make a prior data analysis to determine what event is the actual break according to the information provided by the time series.

Netherlands. We have used Conference Board and Maddison Project Database from 1870 onwards and projected them backwards with estimates by van Zanden and van Leewen's (2012) to 1807 and, then, again, to 1348, on the basis of series for the Holland province, under the assumption that the whole country evolved alongside.

United Kingdom. We have started from the present day definition, Great Britain (that is, England, Wales, and Scotland) and Northern Ireland for which estimates exist back to 1870 (Bank of England, 2018) and projected them back to 1700 using Broadberry et al. (2015) estimates for Great Britain, and, then, for England back to 1270. Again, we assumed that the regions not included evolved alongside. We will use the UK and Britain as synonymous terms in the rest of the paper.

Spain. Prados de la Escosura (2017, updated) series for 1850-2019 were projected backwards to 1277 with Prados de la Escosura et al. (2020) estimates.

Sweden. Conference Board series for 2010-2019 were projected backwards with Krantz and Schön's (2007) series for 1800-2010, then, with Schön and Krantz's (2012), for 1560-1800, and linked to Krantz's (2017) series for 1300-1560.

France. In order to derive yearly series for France over 1280-2019, Conference Board and Maddison Project estimates from 1950 onwards were projected back to 1789 with Toutain's (1997) estimates and, then, again with a revised version of Ridolfi's (2016) series to 1280.

The reason why we have revised Ridolfi's original series is that it presents a flat trend over time that we largely attribute to the way aggregate output has been constructed. In order to obtain per capita output, Ridolfi re-scaled agricultural output per head with an estimate of the share of agriculture in GDP, which was previously derived with the share of agriculture in total labour force and a proxy for agriculture's relative labour productivity, namely, the ratio of agricultural to average wages rates.

Here we have re-calculated Ridolfi's (2016) output per head estimates for 1280-1789 by combining his estimates for agricultural output with the urbanization rate, as a proxy for economic activity in industry and services, using fixed 1781/89 weights. This alternative approach employed is similar to the one used for Spain in Álvarez-Nogal and Prados de la Escosura (2007). In Figure 2 Ridolfi's original and revised series for French GDP per head are presented along the British series. It can be noticed that while France would have fallen behind the UK since the mid-sixteenth century according to Ridolfi's original series, with the revised series France only diverged from Britain since the 1680s. Both estimates probably underestimate French performance in the eighteenth century (Cf. Marczewski, 1960; Morrisson, 2007; Daudin, 2011) and downplay France's relative position to Britain (Crouzet, 1967), but our compromise estimates seem more plausible. Nonetheless, we have replicated our computations with Ridolfi's original series (See Appendix B).

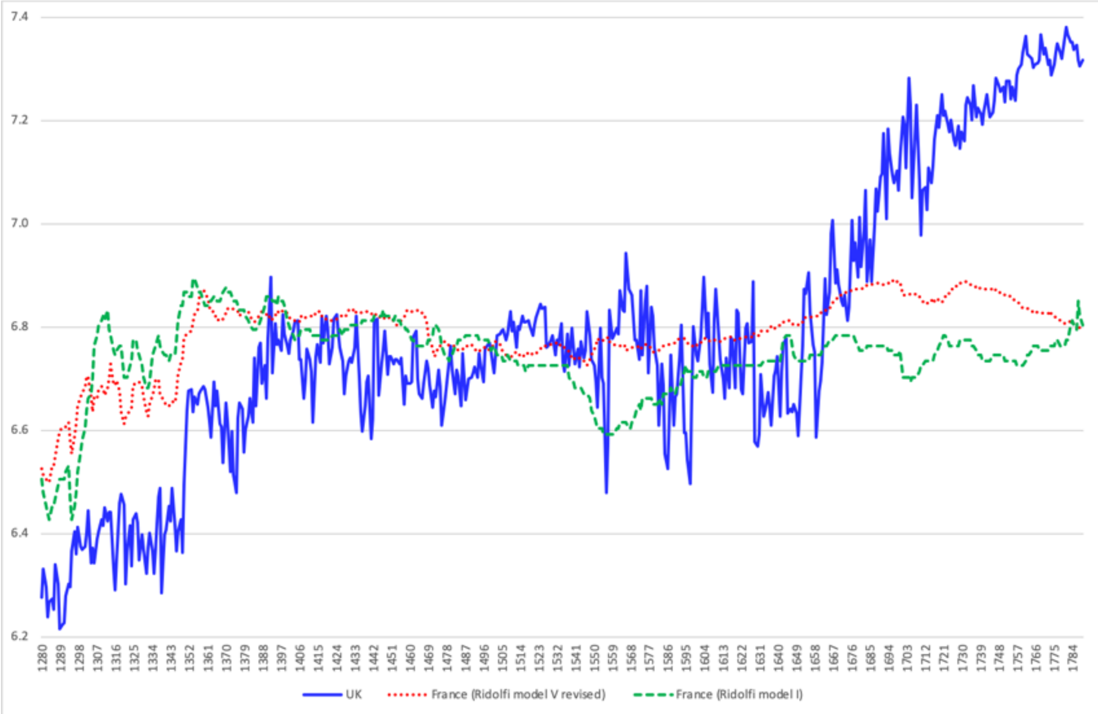

Figure 2. Real GDP per Head in France and Britain, 1280-1789 (G-K$1990, logs)

Portugal. Conference Board and Maddison Project series for 1850-2019 were backwards projected with Palma and Reis (2019) series to 1527.[4] Out of the three alternative series provided by Palma and Reis (2019) using alternatively construction methods similar to 1) Ridolfi's (2016) for France (IPG series), 2) Malanima's (2011) for Italy (Malanima series), and 3) Álvarez- Nogal and Prados de la Escosura's (2013) for Spain (ANPE series), we chose the ANPE series, although Palma and Reis favoured the IPG series. In addition to the reasons exposed to revise Ridolfi's original series for France, we have discarded Palma and Reis' IPG series because it suggests that, in $1990 terms, Portuguese per capita income was similar to the UK's in the late seventeenth and early eighteenth century, a not very plausible result. Alternatively, the ANPE series, although with a similar profile to the IPG series, seem more reasonable with Portugal falling behind the UK since the late 1680s (Figure 3). Our computations have been replicated with Palma and Reis's IPG series for Portugal (Appendix B).

[4] To derive yearly GDP series we had to interpolate industrial and services output to fill missing years between 1850 and 1865.

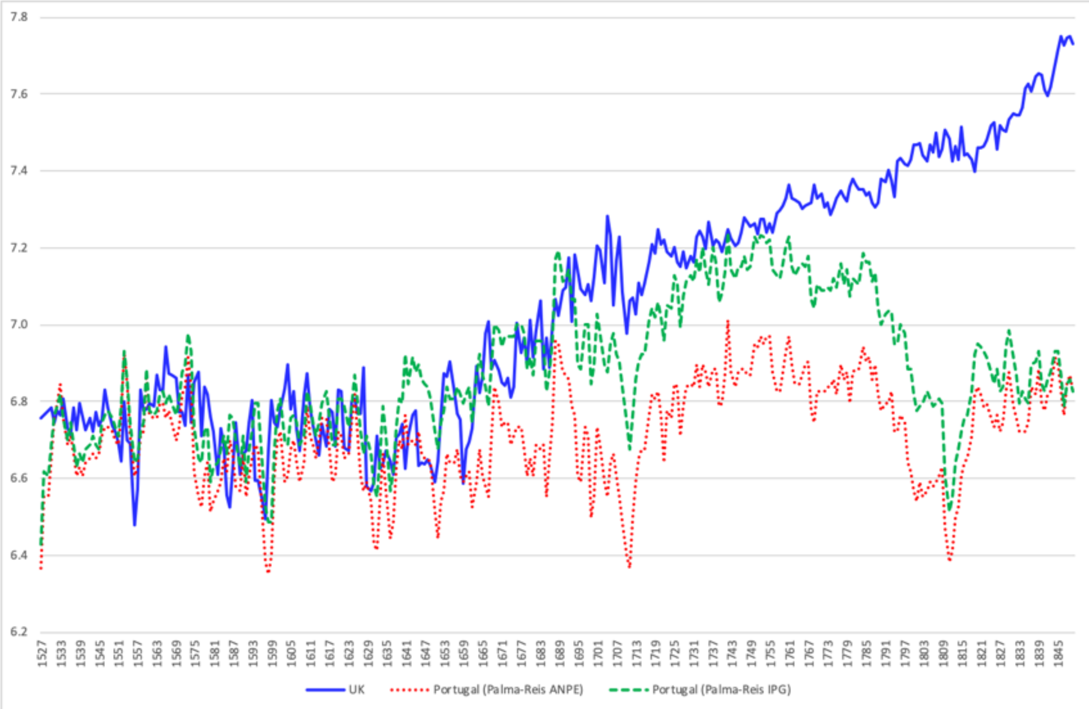

Figure 3. Real GDP per Head in Portugal and Britain, 1527-1850 (G-K$1990, logs)

In order to make the series comparable in levels over space and time we have expressed them in Geary-Khamis 1990 dollars. Thus, for each country we have projected back and forth the 1990 benchmark level derived by Maddison (1995) with the volume indices from historical national accounts. We are aware of the shortcomings of the procedure followed, more specifically, the huge index number resulting from using a fixed benchmark level so remote, but since most of the debate has taken place in terms of G-K$1990 we have accepted them with all the necessary caveats (Prados de la Escosura, 2000).

4. Structural breaks and its persistence in Europe over the long run

Major disruptions, such wars and pandemics, have been deemed the main drivers of income distribution in the very long run (Milanovic, 2016; Scheidel, 2017). The enduring impact of wars provoked shifts in the relative position of countries in terms of income per head. Moreover, historians have established connections between war, state building, and economic success under Mercantilism (Findlay and O'Rourke, 2007; O'Brien, 2018). Were wars and pandemics also the driving forces behind structural breaks?

Table 1 provides information about the different regimes defined by structural breaks for each country in the sample, with confidence intervals, and the trend growth rates for per capita output in each regime. In addition, it provides the fractional memory parameter of each regime estimated by 2ELW and FELW methods. Note that estimation of breaks depends on the trimming parameter, which was calibrated for each individual case. The long memory parameter is estimated with bandwidths $m = T^{0.70}$, where T is the duration of each regime (also displayed in the same table) to avoid higher-frequency contamination.

A first result from Table 1 appears to be that the timing of structural breaks largely coincides across the board. Thus, these breaks define regimes starting around 1340-1370, 1430-1470, 1520-1570, 1620-1650, 1790s-1800s, c.1920, and c.1950. Why? Are there common causes of the structural breaks?

The Black Death and its aftermath marked a structural break across the board ending a phase of rising output per head (regime 1, but for the Netherlands). A long post-Plague regime (reg. 2, but reg. 1 for the Netherlands), that largely overlapped with the Hundred Years' War (1337-1453), was of recovery in some cases (Italy, the Netherlands, and Britain), but also of stagnation (France) and decline (Sweden and Spain), gave way to another break in the mid-fifteenth century. A new regime (reg. 3) opened, with per capita income growth in the Scandinavian and Iberian periphery, but stagnation in Britain and France and decline in Italy.

The next structural break initiated a phase (reg. 4 in most countries) that largely coincided with Hapsburg Spain's European wars, including the annexation of Portugal (1580-1640) (reg. 2 for Portugal) and the Dutch Eighty Years' War (1568-1648). It turns out that while Spain experienced the highest negative trend growth rate in any country of the sample during the seven century span considered, Portugal and the Netherlands exhibit positive trend growth. Sweden, once again, shared Spain's fate, with negative trend growth.

The strong contraction in Spain's real output per head is associated to the efforts to preserve its European Empire. Sustained increases in fiscal pressure on urban activities, the locus of the commercial and industrial expansion in the sixteenth century, in order to finance increasingly expensive imperial wars in Europe, placed an unbearable burden on the most dynamic sectors (Parker, 1975). This triggered de-urbanisation and led to a collapse of average real incomes from which early modern Spain never fully recovered (Prados de la Escosura et al., 2020).

Table 1 Structural Breaks, Regimes, Persistence, and Trend Growth in Europe

	Regime	Period	Duration	CI 95%	FELW	2ELW	CI 95%	Trend Growth (%)
SPAIN	1	1277-1341	65	--	1.00	1.00	(0.81,1.17)	0.06
	2	1342-1440	99	(1439,1444)	0.88	0.96	(0.79,1.13)	-0.27
	3	1441-1559	119	(1558,1560)	0.59	0.62	(0.46,0.77)	0.10
	4	1560-1635	76	(1634,1636)	0.50	0.16	(-0.02,0.35)	-0.60
	5	1636-1794	159	(1790,1795)	0.54	0.57	(0.43,0.71)	0.19
	6	1795-1871	77	(1869,1874)	0.50	0.53	(0.34,0.71)	0.48
	7	1872-1958	87	(1957,1959)	0.87	0.92	(0.74,1.10)	0.69
	8	1959-2019	61	--	0.95	1.00	(0.79,1.20)	2.77
PORTUGAL	1	1527-1575	49	(1573,1577)	0.52	0.91	(0.69,1.12)	0.36
	2	1576-1626	51	(1622,1630)	0.50	0.35	(0.14,0.56)	0.31
	3	1627-1698	72	(1692,1699)	0.50	0.41	(0.22,0.60)	0.29
	4	1699-1747	49	(1746,1749)	0.57	0.66	(0.44,0.87)	0.83
	5	1748-1797	50	(1794,1798)	0.50	0.66	(0.44,0.87)	-0.26
	6	1798-1857	60	(1856,1861)	0.71	0.77	(0.57,0.97)	0.66
	7	1858-1916	59	(1914,1917)	0.84	0.88	(0.68,1.08)	0.65
	8	1917-1966	50	(1965,1967)	0.83	0.98	(0.76,1.19)	2.14
	9	1967-2019	53	--	0.99	0.98	(0.77,1.18)	2.23
ITALY	1	1310-1369	59	(1361,1370)	0.64	0.66	(0.46,0.86)	0.13
	2	1370-1430	60	(1429,1432)	-0.05	0.01	(-0.19,0.21)	0.61
	3	1431-1619	188	(1618,1628)	0.28	0.36	(0.22,0.49)	-0.17
	4	1620-1710	90	(1708,1711)	0.35	0.59	(0.42,0.76)	-0.07
	5	1711-1803	92	(1802,1807)	0.62	0.64	(0.46,0.80)	-0.21
	6	1804-1876	72	(1875,1877)	0.43	0.51	(0.32,0.69)	0.00
	7	1876-1958	82	(1957,1959)	1.06	1.13	(0.95,1.31)	1.00
	8	1959-2019	60	--	0.98	1.01	(0.81,1.21)	1.98
FRANCE	1	1280-1375	96	(1374,1376)	1.06	1.14	(0.97,1.30)	0.30
	2	1376-1471	96	(1469,1472)	1.33	1.50	(1.33,1.66)	-0.01
	3	1472-1668	197	(1666,1669)	1.08	1.11	(0.98,1.24)	0.03
	4	1669-1816	148	(1815,1817)	1.13	1.02	(0.87,1.16)	-0.08
	5	1817-1916	100	(1914,1917)	0.50	0.31	(0.15,0.48)	1.26
	6	1917-2019	103	--	1.13	1.21	(1.04,1.37)	2.36

Table 1 (continued). Structural Breaks, Regimes, Persistence, and Trend Growth in Europe

	Regime	Period	Duration	CI 95%	ELW	TSELW	CI 95%	Trend Growth (%)
SWEDEN	1	1300-1371	72	(1368,1374)	0.99	1.13	(0.81,1.18)	0.06
	2	1372-1448	77	(1446,1449)	1.34	1.48	(1.16,1.53)	-0.28
	3	1449-1523	75	(1522,1544)	1.40	1.54	(1.22,1.58)	0.34
	4	1524-1608	85	(1607,1637)	1.14	1.25	(0.96,1.31)	-0.19
	5	1609-1797	189	(1794,1798)	1.26	1.31	(1.13,1.39)	0.05
	6	1798-1869	72	(1868,1870)	0.98	1.06	(0.80,1.17)	0.41
	7	1870-1946	77	(1945,1947)	0.66	0.69	(0.47,0.84)	1.84
	8	1947-2019	73	--	1.18	1.27	(1.01,1.35)	1.98
NETHERLANDS	1	1348-1576	229	(1570,1577)	0.61	0.60	(0.46,0.74)	0.24
	2	1577-1651	75	(1647,1654)	0.22	0.23	(0.04,0.43)	0.10
	3	1652-1806	155	(1804,1807)	0.50	0.51	(0.32,0.69)	0.19
	4	1807-1946	140	(1945,1947)	0.71	0.75	(0.61,0.89)	0.79
	5	1947-2019	73	--	1.11	1.23	(1.08,1.38)	2.23
UNITED KINGDOM	1	1270-1350	81	(1349,1353)	0.46	0.43	(0.23,0.63)	0.11
	2	1351-1426	76	(1425,1443)	0.53	0.60	(0.40,0.81)	0.25
	3	1427-1502	76	(1469,1505)	0.06	0.10	(-0.1,0.31)	0.00
	4	1503-1628	126	(1627,1629)	0.43	0.45	(0.27,0.62)	-0.05
	5	1629-1708	80	(1707,1712)	0.50	0.47	(0.27,0.67)	0.76
	6	1709-1834	126	(1833,1835)	0.56	0.69	(0.52,0.87)	0.33
	7	1835-1920	86	(1919,1921)	0.74	0.65	(0.45,0.84)	0.95
	8	1921-2019	99	--	0.99	1.07	(0.88,1.26)	2.08
NORTH SEA AREA	1	1348-1427	80	(1426,1451)	0.65	0.73	(0.54,0.91)	0.29
	2	1428-1679	252	(1678,1683)	0.50	0.40	(0.28,0.52)	0.11
	3	1680-1808	129	(1807,1809)	0.54	0.57	(0.42,0.72)	0.25
	4	1809-1920	112	(1919,1921)	0.57	0.60	(0.44,0.76)	1.00
	5	1921-2019	99	--	1.00	1.07	(0.91,1.24)	2.10

Sources: See the text.
Notes: Estimation of trending regimes by BP methodology, and estimation of memory parameters by FELW and 2ELW methods with a bandwidth of $m = T^{0.70}$. CI 95% represents the confidence intervals at 95% of 2ELW estimates, and are computed using the asymptotic distribution given in equation 1. Trend growths are computed after estimating equation 2, and column "Trend Growth (%)" shows slope estimates $\hat{\beta}_{1j} \times 100$ in each regime j.

The Thirty Years' War (1618-1648), that mostly corresponded with a major episode of plague, matched another structural break (reg. 5 for Spain, Sweden, and Britain; reg. 4 for Italy, and reg. 3 for Portugal), but for France (reg. 4), delayed to the last thirds[5] of the century, and giving way to long stagnation until Waterloo. Positive linear trend growth prevailed in the new regime, except in France and, once again, Italy, in which Britain excelled.

Britain's trend growth rate more than doubled any previous expansion phase in Western Europe. This represents an early success, at odds with the narrative that associates modern economic growth to the impact of the institutional changes brought by the Glorious Revolution (North and Weingast, 1989) and that suggests, instead, the effects of the institutional reforms in the aftermath of the civil war and republican rule (1640-83) (O'Brien, 2018).

A less widespread structural break, involving only Portugal (reg. 4), Italy (reg. 5), and Britain (reg. 6), happened at the time of the Spanish Succession War (1701-14) that led Portugal to achieve one of the fastest trend growth in pre-1820 Europe -partly offset by a contraction after a singular structural break in 1748-, while Britain slowed down, and Italy kept contracting.

The Napoleonic Wars (1793-1815) witnessed a structural break in continental Europe, that was differed to the first third of the nineteenth century in the British case (reg. 7). The new regime brought a trend growth acceleration across the board (with Italy's exception reg. 6) in which the French (reg. 5) and British economies did stand out. The institutional reforms triggered across western Europe by the Napoleonic invasion and the collapse of Absolutism may have facilitated the onset of modern economic growth (Pfister, 2017; Prados de la Escosura and Santiago-Caballero, 2018).

The last structural breaks appeared in the aftermath of the World Wars, the UK, Portugal (reg. 8), and France (reg. 6), after World War I and all countries, but the UK and France, after World War II, with positive and strong linear trend growth during the subsequent regimes.

A second aspect in Table 1 to be considered is the persistence of the shocks' impact in terms of memory parameter d. Pandemic disease has been recently considered more persistent over time than any other event, war included (Jordá et al., 2020). In the preindustrial world, however, the difference between the effects of pandemics and war was blurred as pandemics were often diffused across national boundaries by long lasting wars (Voigtländer and Voth, 2013a).

[5] To the last quarter in Rinaldi's original GDP series are considered.

A glance to Table 1 suggests that the structural break originated by the Black Death represented a very persistent regime in Spain, France, and Sweden with $d_{2ELW} = 0.96,\ 1.14,$ and 1.16, respectively. This implies that the Black Death constituted a permanent shock in these countries until the regime transitioned to the next one. In the cases of Britain and the Netherlands the impact of Black Death originated a regime with a lower persistence (0.43 and $0.60, r$espectively). Confidence intervals of d at 95% cover the boundary between stationary and nonstationary regions indicating that this shock was neither permanent in Britain nor in the Netherlands, but it had transitory effects in both countries reverting to the trending path, although much more slowly than in Crafts and Mills (2017: 142). Only in the case of Italy a short memory process appears. The subsequent structural breaks, often concomitant with wars, had a lower degree of persistence. Only in the twentieth century, structural breaks around world wars, exhibit strong persistence across the board.

It is worth pointing out that persistence varies widely across countries. Thus, Sweden and France (but for the nineteenth century) show strong persistence while Italy, the Netherlands, Portugal, and the United Kingdom range between low and medium persistence during the preindustrial era. Spain presents medium levels between the mid-fifteenth and late nineteenth centuries, but strong persistence otherwise.[6]

4.1 Malthusian Europe?

The joint outcome of wars and pandemics prior to Napoleonic Wars was, according to Voigtländer and Voth (2013a), an increase in the endowment of land and capital per survivor which resulted in higher output per head. Urbanization and military expenditure stimulated by higher average incomes would lead to new wars, spread of disease, and, thus, to another push to land and capital per worker resulting in higher output per head. This way, achieving higher income levels would be compatible with a Malthusian context.

Does the evidence presented here fit in this interpretative framework?. In the North Sea Area, a permanent higher income level followed the Plague, but the structural break that occurred at the time had a comparatively less persistent impact in the Netherlands and Britain (regimes 1 and 2, respectively). Furthermore, war affected much less Britain than continental Europe (Figures 4a-4g).

6 The results for Portugal and France in this section are similar when the alternative IPG and Ridolfi original GDP estimates are used (Appendix B).

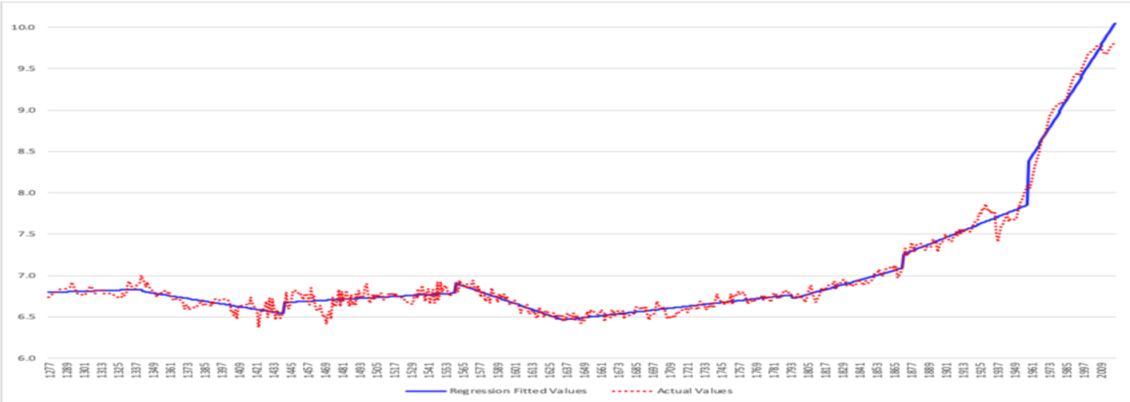

Figure 4a. GDP per Head: Spain, 1277-2019: Trend and Original values (trimming parameter h = 0.09)

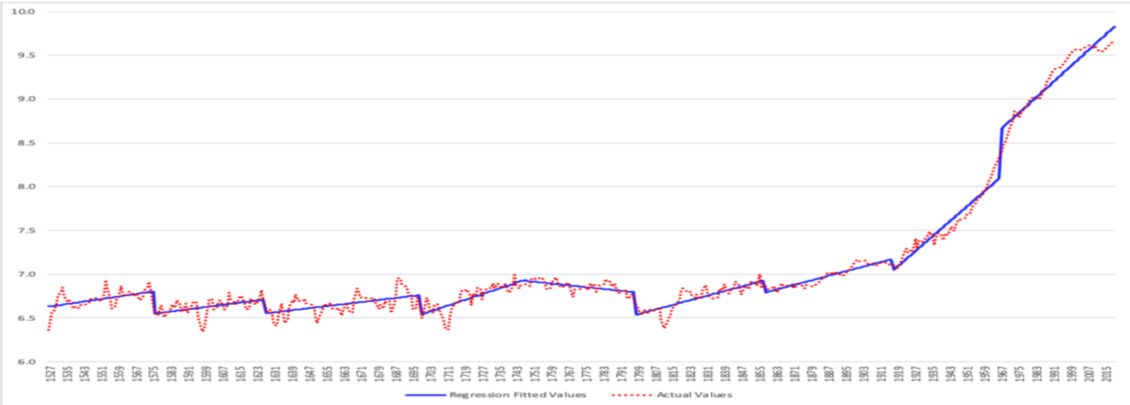

Figure 4b. GDP per Head: Portugal, 1527-2019: Trend and Original values (trimming parameter h = 0.10)

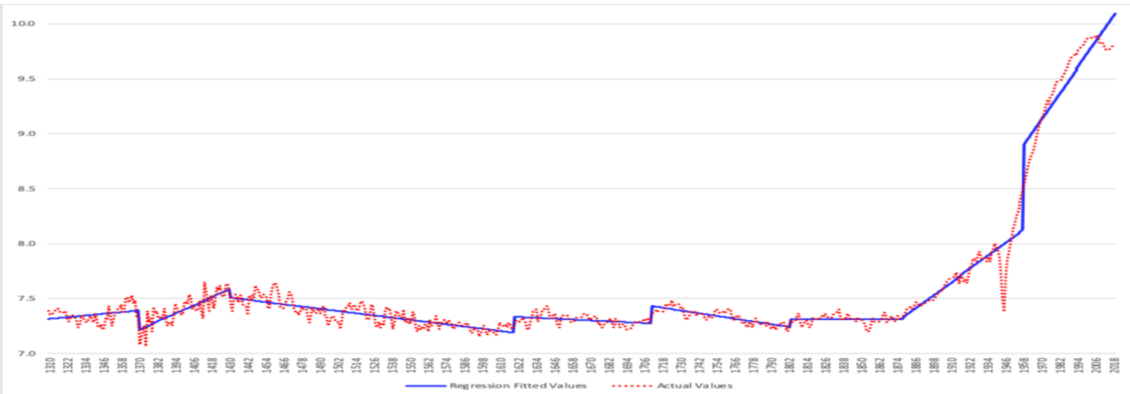

Figure 4c. GDP per Head: Italy, 1310-2019: Trend and Original values (trimming parameter h = 0.08)

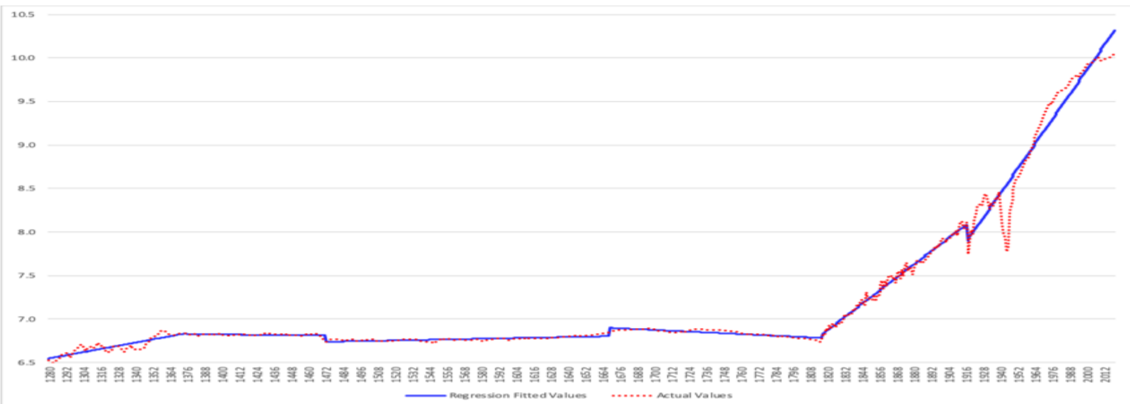

Figure 4d. GDP per Head: France, 1280-2019: Trend and Original values (trimming parameter h = 0.13)

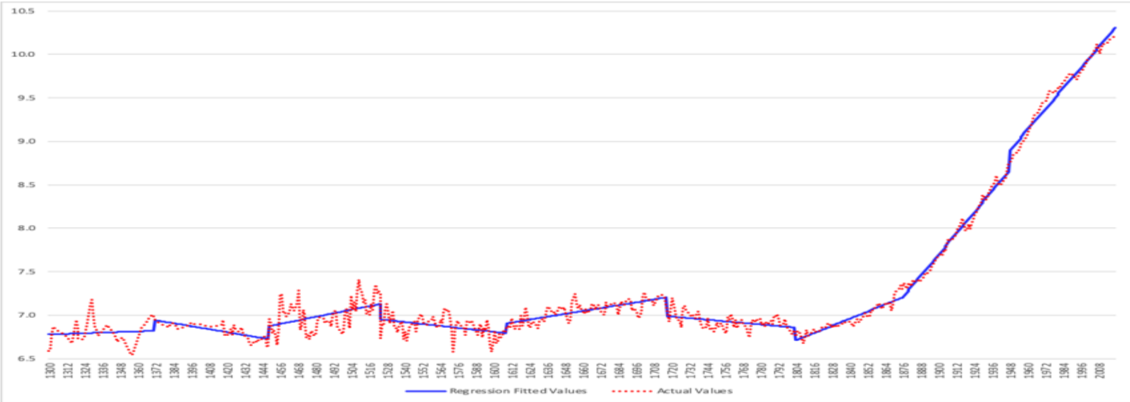

Figure 4e. GDP per Head: Sweden, 1300-2019: Trend and Original values (trimming parameter h = 0.10)

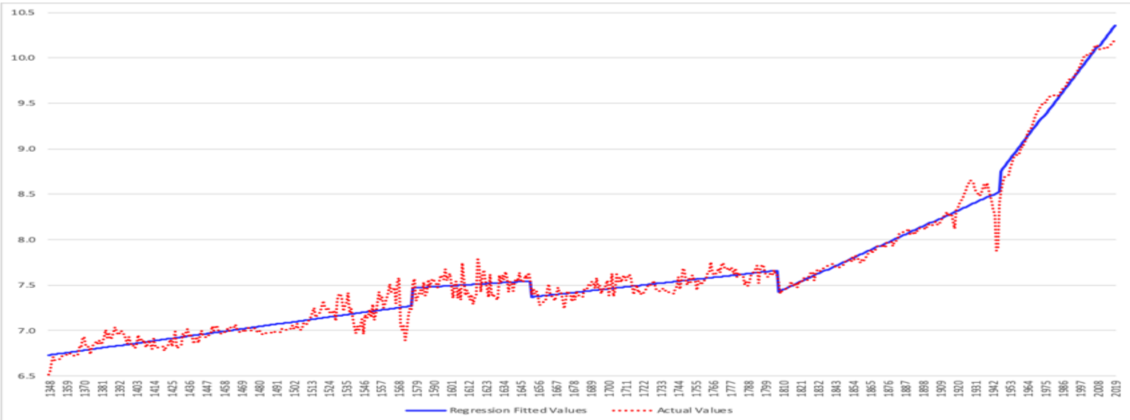

Figure 4f. GDP per Head: The Netherlands, 1348-2019. Trend and Original Values (h = 0.11)

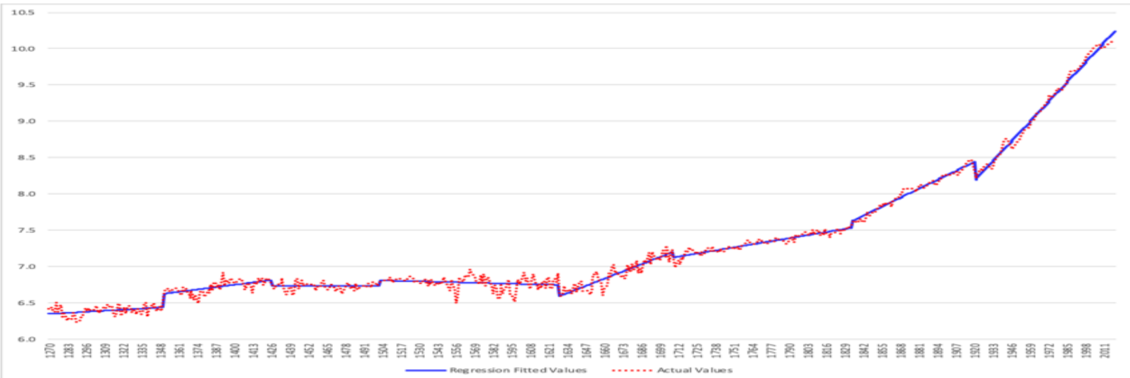

Figure 4g GDP per Head: The United Kingdom, 1270-2019: Trend and Original values (h = 0.10)

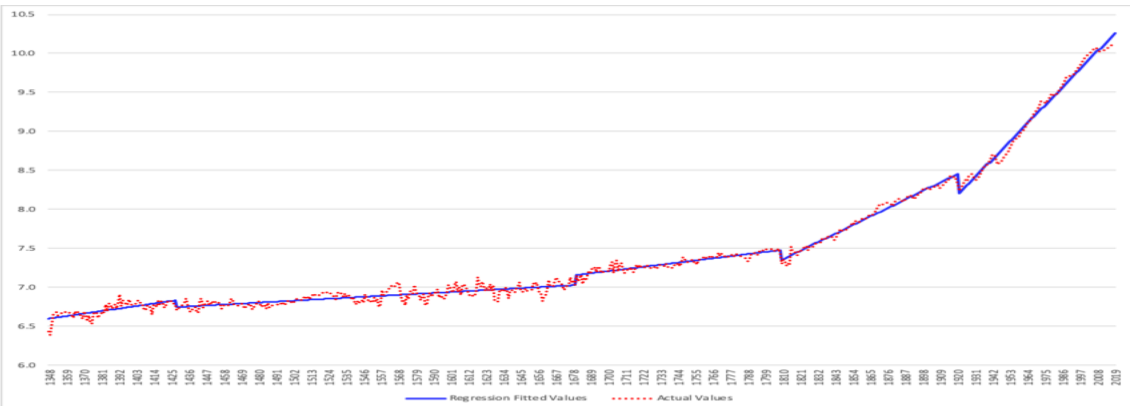

Figure 4h. GDP per Head: The North Sea Area*, 1270-2019: Trend and Original Values (h = 0.10)
* Population weighted average of British and Dutch GDP per head

The case of Italy, with a trend growth rate of 0.61 percent over 1370-1430, appears to confirm Voigtländer and Voth's (2013b) argument that the Black Death would have pushed average income to high levels that would not be reached again until centuries later, as post-Plague income levels were not recovered there until the late 19th century (Figure 4c). However, a similar thrust effect of pandemics and/or war does not seem to have taken place in Italy again. In fact, Italian economic decline in the seventeenth century has been associated to severe pandemic (Alfani, 2013).

The cases of France and Spain appear to contradict Voigtländer and Voth's view because it was the pre-Plague level the one that was not reached again until the late 17th and early 19th century, respectively (Figures 4a and 4d).[7]

The existence of Malthusian behaviour would be evinced by the opposite tendencies of GDP per head and population. Figures 5a-5h present, for each of the countries in the sample, GDP trend growth decomposed into the contributions of GDP per head and population in each regime. The evidence fits the Malthusian pattern for most countries in different periods: Britain until the seventeenth century, France up to the Napoleonic Wars, Italy until its Unification, the Netherlands during the late seventeenth and eighteenth centuries, Sweden during the sixteenth and eighteenth centuries 8, and Portugal in the 1700s. However, this does not seem to fit the case of Sweden until the early 1500s or Spain, in which GDP per head and population evolved alongside over the whole considered period and, even when they show opposite signs, as in 1560-1635, the negative output per head growth goes along a sharp deceleration in population growth.

It worth stressing that the post-Black Death trend growth acceleration appears to be consistent with the Malthusian narrative for most countries, but how to explain the negative trend growth in Spain and Sweden? The existence of a frontier economy with abundant natural resources and scarce population provides an explanatory hypothesis. The fact that factor proportions, namely, high land-labour ratios in pre-Plague Spain and Sweden were similar to those in post-Plague western Europe (Pamuk, 2007) helps explain why the Black Death had only negative consequences for their economies. In Spain, the pre-existing fragile equilibrium between resources and labour was broken by the Black Death with devastating economic consequences, despite its comparatively milder demographic impact (Álvarez-Nogal and Prados de la Escosura 2013).

7 With Ridolfi's original series France would reach pre-Plague level again in the early 19th century (Figure 2).

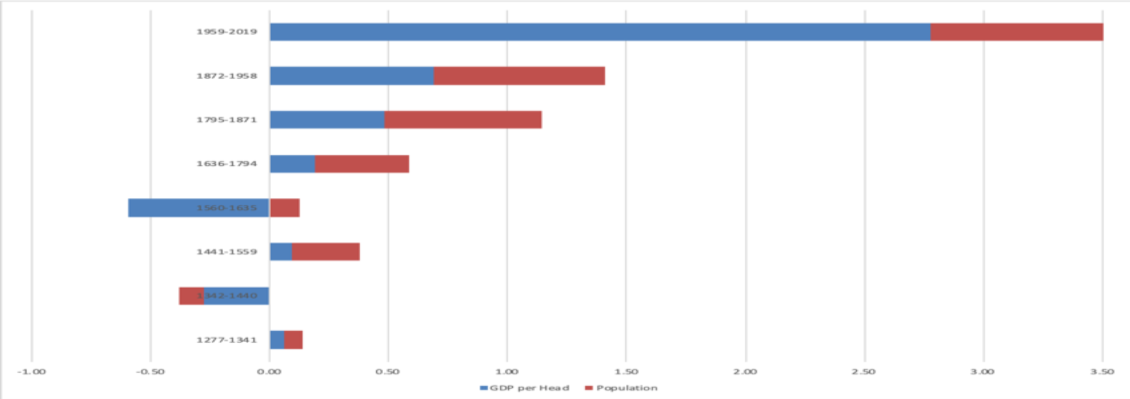

Figure 5a. Trend Growth in GDP and its Components: Spain, 1277-2019 (%).

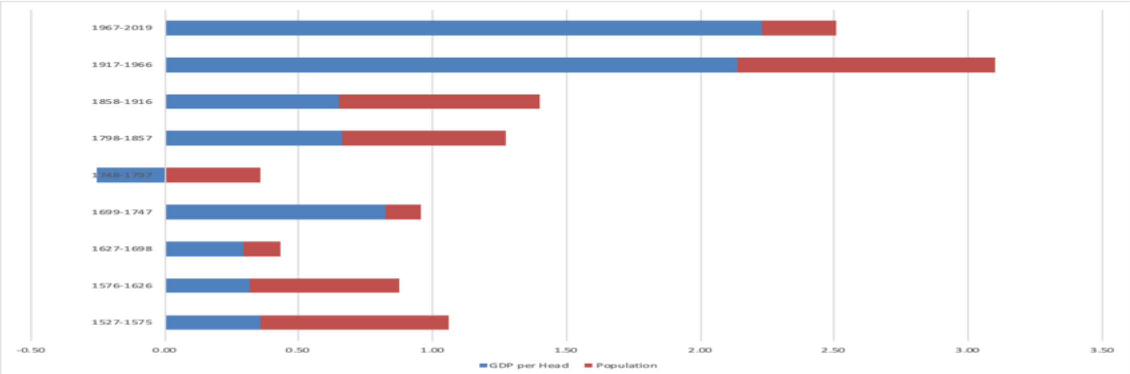

Figure 5b. Trend Growth in GDP and its Components: Portugal, 1527-2019 (%).

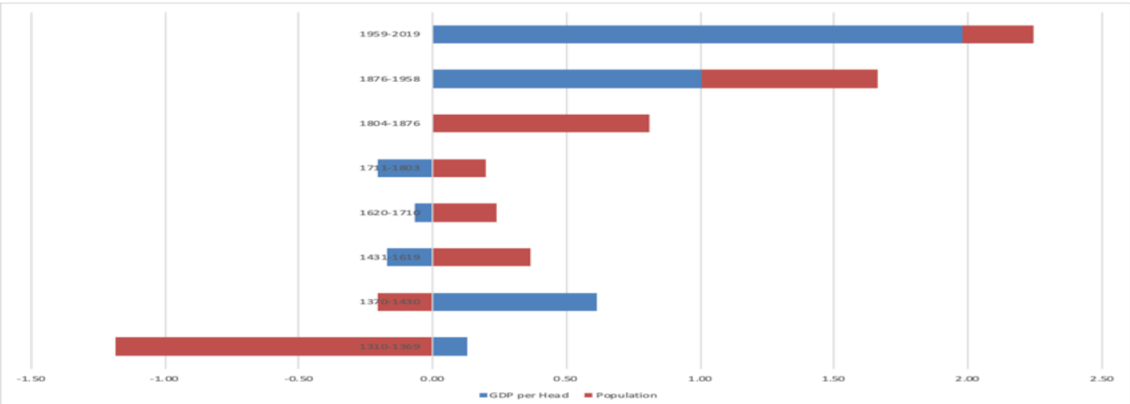

Figure 5c. Trend Growth in GDP and its Components: Italy, 1310-2019 (%).

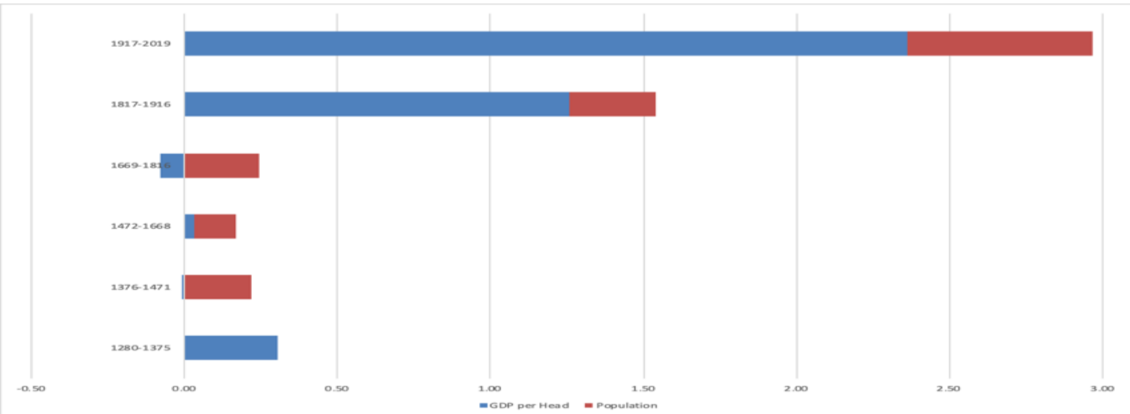

Figure 5d. Trend Growth in GDP and its Components: France, 1280-2019 (%).

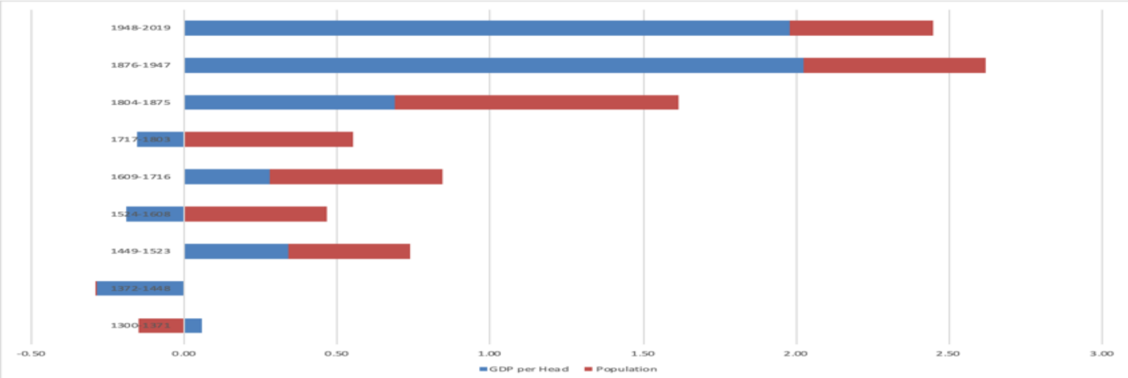

Figure 5e. Trend Growth in GDP and its Components: Sweden, 1300-2019 (%).

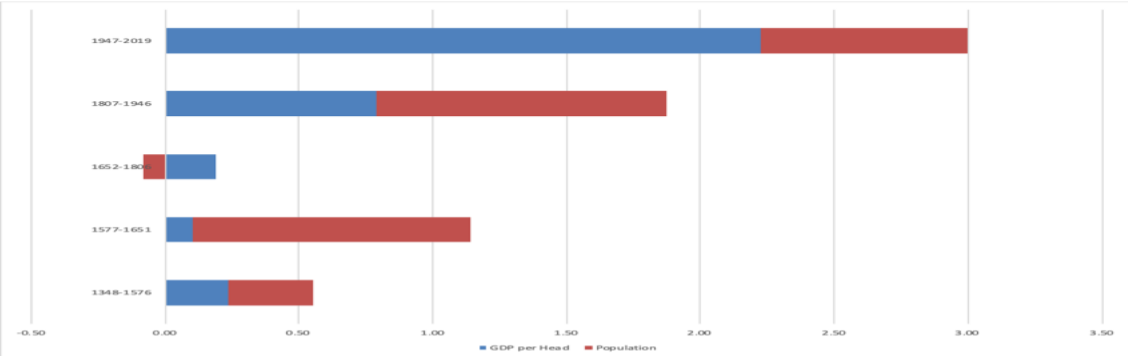

Figure 5f. Trend Growth in GDP and its Components: the Netherlands, 1348-2019 (%).

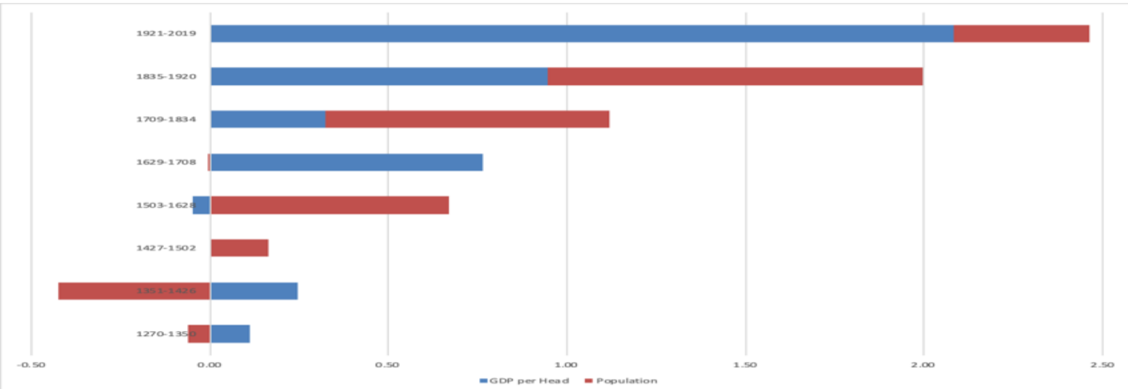

Figure 5g. Trend Growth in GDP and its Components: the United Kingdom, 1270-2019 (%).

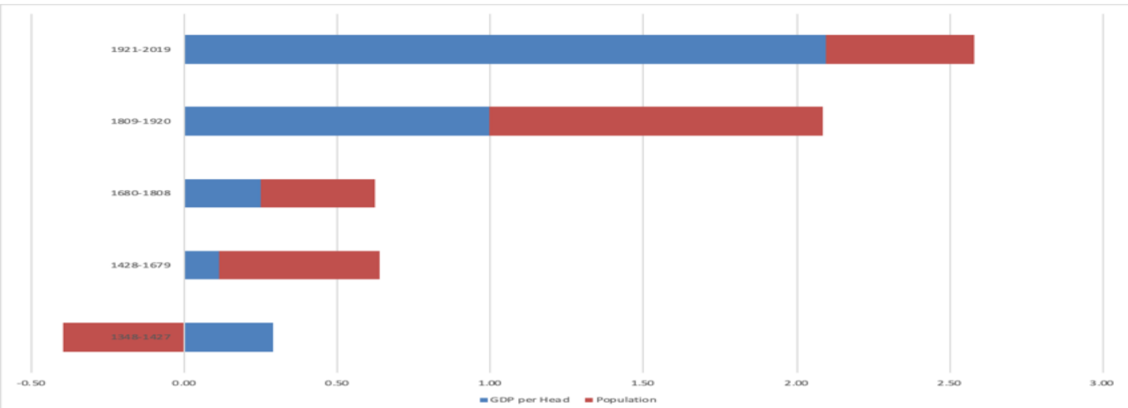

Figure 5h. Trend Growth in GDP and its Components: the North Sea Area*, 1270-2019 (%).
* Population weighted average of British and Dutch GDP per head

Furthermore, the frontier economy may also help to explain the inverse behaviour of Sweden and Spain to the rest of the country sample way after the Black Death.

What does the evidence examined tells us about the origins of modern economic growth? All countries present trend growth reversals but the Netherlands and Britain; in the rest of continental Europe, irreversible growth only took place from the Napoleonic Wars (1793-1815) onwards and peak levels achieved in earlier periods were not overcome until, at least, the early nineteenth century.

In Britain, no growth reversals exist, even though zero trend growth is found between 1427 and 1628, so a positive trend growth emerges since 1270. Nonetheless, trend growth accelerated since the first third of the 17th century, making Britain a precocious case in Europe. In the Netherlands, the absence of growth reversals implies a positive trend growth since 1348, although an acceleration took place after 1807.

Thus, if we approach the question at individual country level, it is possible to claim that while the Netherlands experienced mild growth trend in real output per head since the post-Plague era, in the case of Britain, trend growth can be dated from the early 1600s, confirming previous findings by Crafts and Mills (2017). Yet, if we look at regions, rather than countries, it emerges that positive trend growth went along a sustained increase in population in the North Sea Area since the Black Death (Figures 4h and 5h).

5. The *Little Divergence*

The absence of growth reversals in Britain and the Netherlands would explain why the two North Sea Area countries forged ahead the rest of Europe until World War I, triggering the so-called *Little Divergence*.

However, the definition and timing of the *Little Divergence* has been rather casual so far. Time series analysis can be used to assess more rigorously the patterns of the *Little Divergence* between each European country and the North Sea Area, namely, Britain and the Netherlands, from the Black Death to the eve of World War I which is the relevant period for the historical debate.

The early literature introduced the terms beta- and sigma-convergence, that represent an inverse association between the rate of variation and the initial level and a reduction of the dispersion, respectively (Barro and Sala-i-Martin, 1992). Bernard and Durlauf (1996) argued that the time-series approach to convergence allowed the distinction between weak stochastic convergence or catching-up and strong deterministic convergence (Cf.. Johnson and Papageorgiou, 2020).

In the debate on the European *Little Divergence*, however, none of these concepts are employed and instead the gap between each country and the "leader", whose place is alternatively filled by Britain or the North Sea Area, has been chosen. Thus, a country diverges when its output per head declines relative to that of the North Sea Area (namely, the population average of British and Dutch per capita GDP) and, *stricto sensu*, when it falls behind.

In this section we investigate the European *Little Divergence* using a time-series approach. We opted to follow Bernard and Durlauf's (1996) approach extended by Gómez-Zaldívar and Ventosa-Santaulària (2012). The idea is that the outcomes of the European *Little Divergence* analysis are based on the statistical properties of

$$y_{i,t} = x_{i,t} - nsa_t \,, \qquad (3)$$

where in year t, x_i represents the log of GDP per head in the country i (Spain, Portugal, Italy, France, or Sweden) and nsa represents the log of GDP per capita in the North Sea area, which is taken as the "leader" in the analysis.

Our methodology is as follows: First, we estimate the breakpoints in $y_{i,t}$ for each country i by BP method as in Section 2 in order to identify regimes. Then, for the particular regime j in the country i, we investigate by standard econometric methods, which data generating process (DGP) is characterizing the process $\{y_{it,j}\}_{t=1}^{T}$, that is the relative income of the country i with respect to the yardstick North Sea area along regime j. We have six different possibilities:

a) Long-run convergence: the log difference in per capita GDP between country i and the North Sea Area (the yardstick economy) is mean-stationary, that is, country i's relative income series remains stable over time.

b) Catching-up (lagging-behind): the relative income series ($y_{i,t}$) is stationary around a positive (negative) deterministic trend.

c) Loose catching-up (loose lagging-behind) represents a weak catching-up (lagging-behind) as the relative income series contains a positive (negative) deterministic trend and a stochastic trend simultaneously.

d) Divergence: country i's relative income series follows a random walk, which is interpreted as the disparity is unpredictable.

Table 2 provides the results. Let us examine each country individually. In the case of Spain (Figure 6a), regimes 1 (1348-1439) and 3 (1598-1690) correspond to “lagging-behind”, that is, the difference in terms of per capita income deepens because the relative income of Spain represents a stationary series around a negative deterministic trend, while regime 4 (1691-1829) corresponds to “catching-up”, that is, Spain’s relative GDP per head series is stationary but with positive deterministic trend, in the Augmented Dickey-Fuller(ADF) test, but implies “long-run convergence” in the Phillips-Perron (PP88) test, as the relative income series is mean-stationary and the disparity between the per capita GDP of Spain and the North Sea Area is stable. Such difference is related to how the unit root test chooses the number of lags and work with deterministic trends. However, regime 2 (1440-1597), like regime 5 (1830-1913), would be of “long-run convergence”.

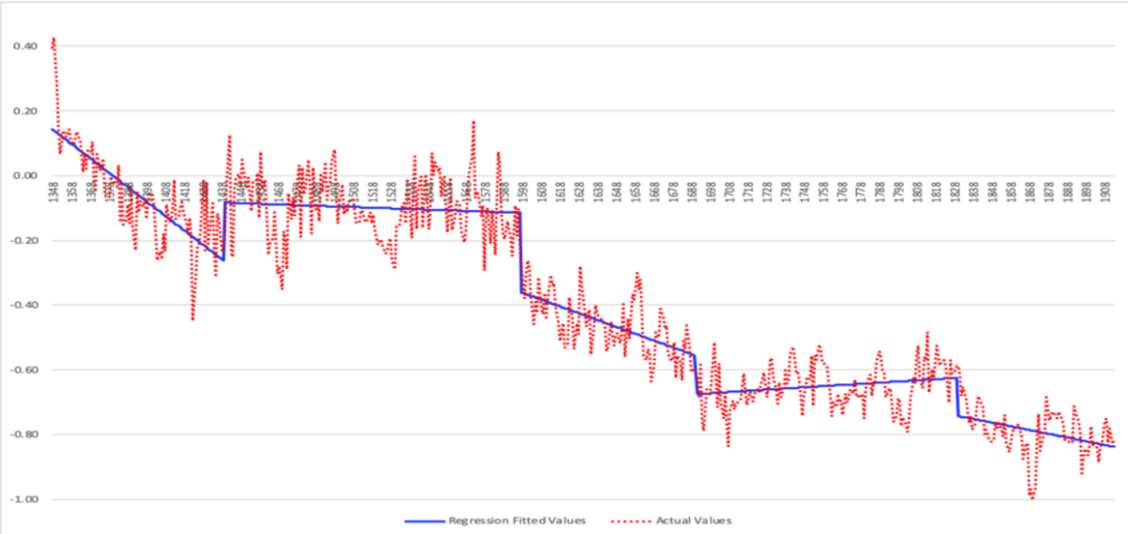

Figure 6a. The Little Divergence: Spain and the North Sea Area, 1348-1913.

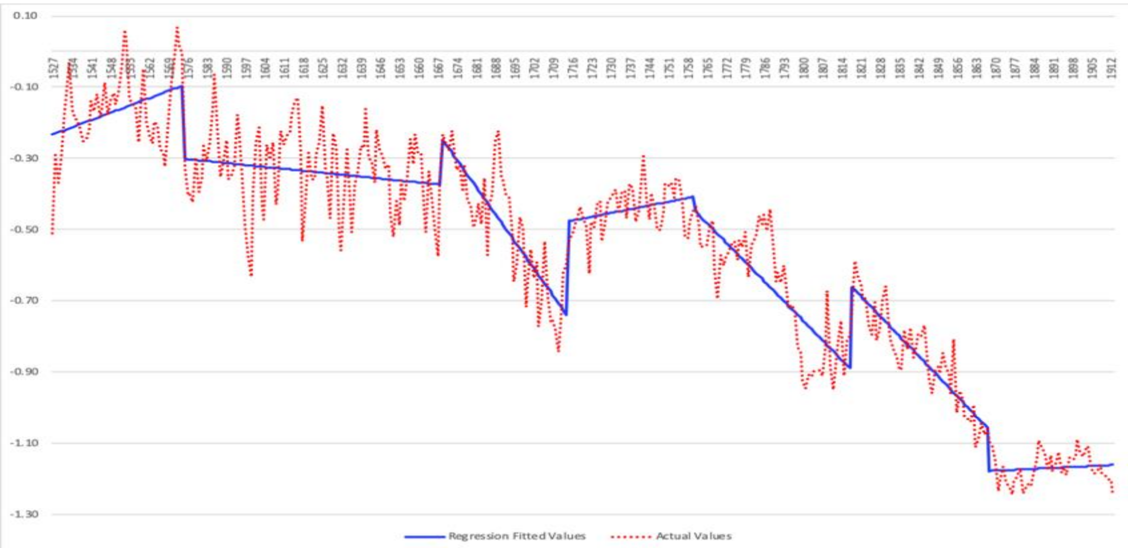

Figure 6b. The Little Divergence: Portugal and the North Sea Area, 1527-1913.

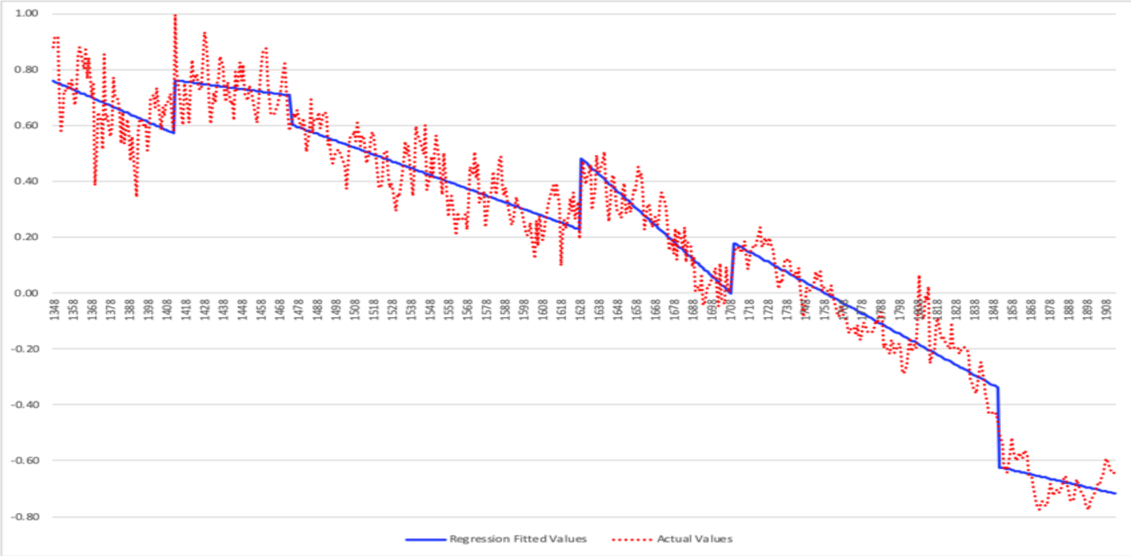

Figure 6c. The Little Divergence: Italy and the North Sea Area, 1348-1913.

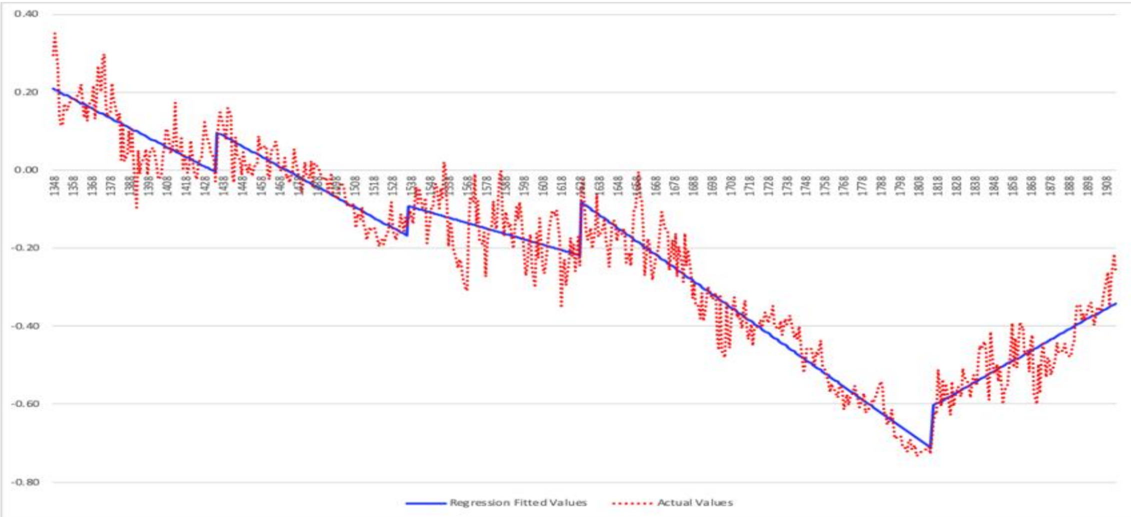

Figure 6d. The Little Divergence: France (revised) and the North Sea Area, 1348-1913.

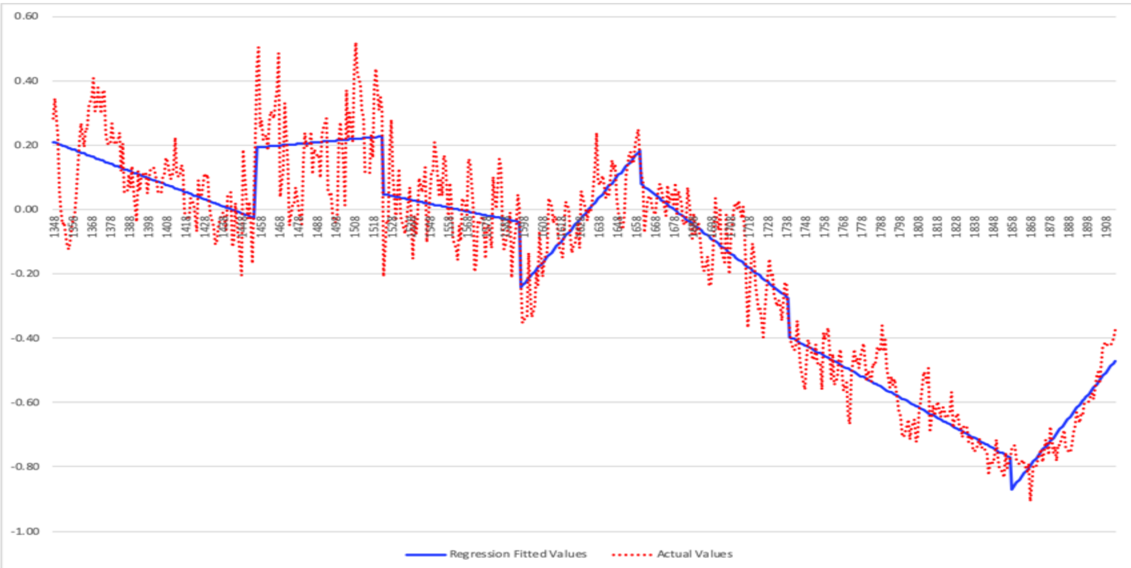

Figure 6e. The Little Divergence: Sweden and the North Sea Area, 1348-1913.

In the case of Portugal (Figure 6b), regimes 1 (1527-1574), 2 (1575-1668), and 4 (1715-1760) are depicted as regimes of “long-run convergence” (“catching-up” for regime 4, in the ADF test), while regimes 3 (1669-1714) and 6 (1818-1867) are of “lagging-behind”, and, in the case of regime 5 (1761-1817), is of “divergence”, a depiction shared by regime 7 (1868-1913).[8]

A similar exercise for the case of Italy (Figure 6c) shows that the country experienced a process of “lagging-behind” in all regimes but in regime 2 (1413-1474) when exhibits “long-run convergence”, and regime 6 (1852-1913) that appears to be of “divergence”, that is, the series follows a random walk and its evolution is unpredictable.

If the exercise is replicated for France (Figure 6d), the first four regimes, covering 1348-1815, are depicted as “lagging-behind”, with only regime 5 (1816-1913) defined as one of “catching-up”.[9]

Lastly, in the case of Sweden (Figure 6e), regimes 1 (1348-1455), 3 (1524-1596), 5 (1661-1739), and 6 (1740-1857) imply “lagging-behind”, while regimes 2 (1456-1523), “long-run convergence”, 4 (1597-1660), “catching-up”, and 7 (1858-1913) “loose catching-up” -meaning the simultaneous existence of a positive deterministic trend and a stochastic trend-.

These results confirm that opposite tendencies gradually arose between the North Sea Area and the rest of the European economies with lagging-behind” (and “divergence”) trending regimes spreading between the aftermath of the Black Death and World War I.

Can these results be interpreted in the light of the *Little Divergence* approach? If a strict definition of *divergence* is applied, namely, a country falling behind the North Sea Area in terms of GDP per head with the result of a widening gap, Spain would have exhibited *divergence* in the seventeenth century; Portugal, from late seventeenth century up to Utrecht peace (1713) and, again, after the Napoleonic Wars; Italy, from the late eighteenth century onwards, and France and Sweden between the early and late seventeenth century, respectively, to the Napoleonic Wars. It can be argued, then, that the *Little Divergence* gradually took place from the seventeenth century onwards.

We can conclude that, although different assessments of the performance of European countries relative to the North Sea Area derive from using a *Little Divergence*

[8] The results are very similar when the alternative IPG GDP estimates are used (Appendix B)

[9] The results are practically identical when Ridolfi’s original GDP estimates are employed (Appendix B).

Table 2 The *Little Divergence*: Structural Breaks, Regimes, and Trend

	REGIME	Period	Breaks at 95%	Duration	ADF	Trend Growth (%)	PP88	Trend Growth (%)
SPAIN	1	1348-1439	(1438,1446)	92	lagging-behind***	-0.210***	lagging-behind***	-0.224***
	2	1440-1597	(1596,1604)	158	long-run convergence***		long-run convergence***	--
	3	1598-1690	(1686,1691)	93	lagging-behind***	-0.104***	lagging-behind***	-0.105***
	4	1691-1829	(1827,1841)	139	catching-up***	0.015***	long-run convergence***	--
	5	1830-1913		84	long-run convergence***	--	long-run convergence***	--
PORTUGAL	1	1527-1574	(1573,1581)	48	long-run convergence*	--	long-run convergence**	--
	2	1575-1668	(1664,1669)	94	long-run convergence***	--	long-run convergence***	--
	3	1669-1714	(1713,1718)	46	lagging-behind*	-0.581*	lagging-behind**	-0.544**
	4	1715-1760	(1759,1761)	46	catching-up**	0.085**	long-run convergence**	--
	5	1761-1817	(1816,1819)	57	divergence	--	divergence	--
	6	1818-1867	(1865,1868)	50	lagging-behind**	-0.508**	lagging-behind***	-0.610***
	7	1868-1913		46	divergence	--	divergence	--
ITALY	1	1348-1412	(1410,1420)	65	lagging-behind**	-0.106**	lagging-behind***	-0.131*
	2	1413-1474	(1472,1495)	62	long-run convergence***	--	long-run convergence***	--
	3	1475-1628	(1625,1629)	154	lagging-behind***	-0.092***	lagging-behind***	-0.096***
	4	1629-1709	(1708,1714)	81	lagging-behind***	-0.315**	lagging-behind***	-0.349***
	5	1710-1851	(1850,1852)	142	lagging-behind**	-0.086**	lagging-behind**	-0.086**
	6	1852-1913		62	divergence	--	divergence	--
FRANCE	1	1348-1434	(1432,1438)	87	lagging-behind***	-0.081**	lagging-behind***	-0.095**
	2	1435-1536	(1532,1545)	102	lagging-behind***	-0.133***	lagging-behind***	-0.129***
	3	1537-1628	(1626,1630)	92	lagging-behind***	-0.063**	lagging-behind***	-0.066**
	4	1629-1815	(1814,1816)	187	lagging-behind***	-0.119***	lagging-behind***	-0.141***
	5	1816-1913		98	catching-up**	0.110**	catching-up***	0.139***
SWEDEN	1	1348-1455	(1452,1466)	108	lagging-behind**	-0.042*	lagging-behind**	-0.048*
	2	1456-1523	(1521,1539)	68	catching-up**	0.088*	long-run convergence**	--
	3	1524-1596	(1593,1597)	73	lagging-behind***	-0.101***	lagging-behind***	-0.095*
	4	1597-1660	(1659,1661)	64	catching-up**	0.299**	catching-up***	0.301***
	5	1661-1739	(1726,1742)	79	lagging-behind***	-0.215***	lagging-behind***	-0.191***
	6	1740-1857	(1856,1858)	118	lagging-behind***	-0.106***	lagging-behind***	-0.113***
	7	1858-1913		56	loose catching-up	0.197*	loose catching-up	0.194*

Sources: See the text.

Notes: Estimation of trending regimes by BP methodology. ADF corresponds to Augmented Dickey Fuller tests, while PP88 is the Phillips-Perron (1988) test. Trend Growth represents slope estimates × 100. Symbols *, **, and *** denote rejection of the null hypothesis (unit root or significance of the trend) at the 10, 5, and 1% levels, respectively.

or a convergence approach, it clearly emerges from them the North Sea Area's distinctive behaviour that cumulated throughout the early modern era.

6. Conclusions

In this paper we have investigated the origins of modern economic growth and the *Little Divergence* in Europe with the help of a 'long memory' approach. Structural breaks in GDP per head defining different phases or regimes are located for a sample of European countries over seven centuries. It is worth noting that structural breaks frequently coincided with wars and pandemics and those that occurred around the Black Death and World Wars I and II were the most persistent.

We find that the Black Death often resulted in higher income levels, as posited by Voigtländer and Voth, but the response to the Plague was far from uniform and not in all countries its effect was permanent. Furthermore, in frontier economies the Black Death affected negatively average income levels.

Our results contradict the binary, stagnation-growth, description of pre- and post-Industrial Revolution economic behaviour. Historical evidence suggests a more nuanced view. Even if an inverse relationship between output per head and population tendencies is often found, the timing differs across countries and a weak, rather than a strict Malthusian pattern fits better the European experience, since average incomes were gradually lifted up between the Black Death and the Napoleonic Wars. Moreover exceptions to the Malthusian regime are not negligible as in frontier economies income per head and population evolved alongside.

A key question in the historical debate is if the onset of modern economic growth took place in Europe before the mid-eighteenth century. We provide an affirmative answer here. When countries are considered individually, we find that, in Britain, trend growth in per capita income occurred since the early 1600s, while in the Netherlands goes back to post-Black Death era, and none of them suffered growth reversals since the Plague. If, alternatively, we focus on distinctive regions, we find that in the North Sea Area, per capita income gains, along population expansion, took place gradually after the Plague.

The absence of growth reversals explain why the North Sea Area forged ahead the rest of Europe until World War I, prompting the *Little Divergence* between the early seventeenth century and the Napoleonic Wars. Thus, our results lend support to Broadberry-van Zanden's interpretation against Goldstone's.

References

Abadir, K. M., W. Distaso, and L. Giraitis (2007), "Nonstationarity-extended Local Whittle Estimation", *Journal of Econometrics* 141 (2): 1353-1384.

Acemoglu, D., S. Johnson, and J.A. Robinson (2005), "The Rise of Europe: Atlantic Trade, Institutional Change, and Economic Growth", *American Economic Review* 92: 546-579.

Álvarez-Nogal, C. and L. Prados de la Escosura (2007), "The Decline of Spain (1500-1850): Conjectural Estimates", *European Review of Economic History* 11 (3): 319-366.

Álvarez-Nogal, C. and L. Prados de la Escosura (2013), "The Rise and Decline of Spain, 1270-1850", *Economic History Review* 66 (1): 1-37.

Baffigi, A.(2012), "National Accounts, 1861-2011", in G. Toniolo (ed.), *The Oxford Handbook of the Italian Economy since Unification*, Oxford: Oxford University Press, pp. 157-186.

Bai, J. (1997), "Estimation of a Change Point in Multiple Regression Models", *Review of Economics and Statistics* 79: 551–563.

Bai, J. and P. Perron (1998), "Estimating and Testing Linear Models with Multiple Structural Changes", *Econometrica* 66: 47-78.

Bai, J. and P. Perron (2003a), "Computation and Analysis of Multiple Structural Change Models", *Journal of Applied Econometrics* 18 (1): 1-22.

Bai, J. and P. Perron (2003b), "Critical Values for Multiple Structural Change Tests", *Econometrics Journal* 6 (1): 72-78.

Baillie, R. T., C.F. Chung, and M.A. Tieslau (1996), "Analysing Inflation by the Fractionally Integrated ARFIMA–GARCH Model", *Journal of Applied Econometrics* 11 (1): 23-40.

Bank of England (2018), A Millennium of Macroeconomic Data for the UK. https://www.bankofengland.co.uk/statistics/research-datasets

Barro, R. and X. Sala-i-Martin (1992), "Convergence", *Journal of Political Economy* 100: 223-251

Beran, J., Y. Feng, S. Ghosh, and R. Kulik (2016), *Long-Memory Processes*, Berlin-Heidelberg: Springer-Verlag.

Bernard, A.B. and S.N. Durlauf (1996), "Interpreting Tests of the Convergence Hypothesis", *Journal of Econometrics* 71: 161-173.

Braudel, F. (1973), *Capitalism and Material Life, 1400-1800*, New York: Harper Collins.

Broadberry, S.N. (2013), Accounting for the Great Divergence, LSE Economic History Working Papers 184.

Broadberry, S.N., B.M.S. Campbell, A. Klein, M. Overton, and B. van Leeuwen (2015), *British Economic Growth, 1270-1870*, Cambridge: Cambridge University Press.

Broadberry, S.N. and J. Wallis (2017), Growing, Shrinking and Long Run Economic Performance: Historical Perspectives on Economic Development, CEPR Discussion Papers 11973.

Canarella, G. And S.M. Miller (2016), "Inflation Persistence and Structural Breaks: The Experience of Inflation Targeting Countries and the USA", *Journal of Economic Studies* 43 (6): 980-1005.

Casini, A., and P. Perron (2018), "Structural Breaks in Time Series," in *Oxford Research Encyclopedia of Economics and Finance*, Oxford: Oxford University Press DOI: 10.1093/acrefore/9780190625979.013.179

Christiano, L. J. (1992), "Searching for a Break in GNP", *Journal of Business and Economic Statistics* 10: 237–250

Clark, G. (2007), *A Farewell to Alms. A Brief Economic History of the World*, Princeton: Princeton University Press.

Conference Board (2019), Total Economy Database Growth. TED 2. Accounting and Total Factor Productivity, 1990-2018.
https://www.conference-board.org/data/economydatabase/index.cfm?id=2776

Crafts, N. and T.C. Mills (2017), "Six Centuries of British Economic Growth: a Time-series Perspective", *European Review of Economic History* 21: 141-158.

Crouzet, F. (1967), "England and France in the Eighteenth Century : A Comparative analysis of Two Economic Growth", in R.M. Hartwell (ed.), *The Causes of the industrial Revolution in England*, London : Methuen, pp. 139-174.

Daudin, G. (2011), *Commerce et prospérité. La France au XVIIIe siècle*, Paris: Presses de l'Université Paris-Sorbonne, Creative Commons 2nd. edition. http://g.d.daudin.free.fr/Page_Web_de_Guillaume_Daudin/Publications_files/Daudin%20-%20Commerce%20et%20Prospe%CC%81rite%CC%81%202e%20e%CC%81dition%20-%202011.pdf

Fouquet, R. and S. Broadberry (2015), "Seven Centuries of European Growth and Decline", *Journal of Economic Perspectives* 29 (4): 227-244.

Frank, A.G. (1998), *ReOrient. Global Economy in the Asian Age*, Berkeley: University of California Press.

Galor, O. (2011), *Unified Growth Theory*. Princeton: Princeton University Press.

Galor, O. and D.N. Weil (2000), "Population, Technology, and Growth: From Malthusian Stagnation to the Demographic Transition and Beyond", *American Economic Review* 90 (4): 806-828.

Geweke, J. and S. Porter-Hudak (1983), "The estimation and application of long memory time series models", *Journal of Time Series Analysis* 4 (4): 221-238.

Gil-Alana, L. A. (2004), "A Fractionally Integrated Model for the Spanish Real GDP", *Economics Bulletin* 3 (8): 1-6

Gil-Alana, L. A. And P.M. Robinson (1997), "Testing of Unit Root and Other Nonstationary Hypotheses in Macroeconomic Time Series", *Journal of Econometrics* 80 (2): 241-268

Goldstone, J.A. (2002), "Efflorescences and Economic Growth in World History: Rethinking 'The Rise of the West' and the Industrial Revolution", *Journal of World History* 13 (2): 323.389.

Goldstone, J.A. (2019), "Data and Dating the Great Divergence", in T. Roy and G. Riello (eds.), *Global Economic History*, London: Bloomsbury, pp. 38-53.

Granger, C. W. and R. Joyeux (1980), "An Introduction to Long-memory Time Series Models and Fractional Differencing", *Journal of Time Series Analysis* 1 (1): 15-29.

Hackl, P. and A.H. Westlund (1989), "Statistical Analysis of 'Structural Change': An Annotated Bibliography", in W. Kramer (ed.), *Econometrics of Structural Change*, Heidelberg: Physica-Verlag, pp. 103-128.

Hansen, G.D. and E.C. Prescott (2002), "Malthus to Solow", *American Economic Review* 92 (4): 1205-1217.

Henriques, A.C. and N. Palma (2019), Comparative European Institutions and the Little Divergence, 1385-1800, CEPR Discussion Paper 14124.

Hosking, J.R.M. (1981), "Fractional Differencing", *Biometrika* 68 (1): 165-176.

Jedwab, R., N.D. Johnson, and M. Koyama (2019), Pandemics, Places, and Populations: Evidence from the Black Death, CEPR Discussion Paper 13523

Johnson, P. and C. Papageorgiou (2020), "What Remains of Cross-Country Convergence?", *Journal of Economic Literature* 58 (1): 129–175

Jones, E.L. (1981), *The European Miracle: Environments, Economies and Geopolitics in the History of Europe and Asia*, 2nd edition. Cambridge: Cambridge University Press.
Jones, E.L. (1988), *Growth Recurring*: *Economic Change in World History*, Oxford: Oxford University Press.
Jordá, O., S.R. Singh, and A.M. Taylor (2020), "Longer-Run Economic Consequences of Pandemics", *Covid Economics* 1 (3): 1-15.
https://cepr.org/sites/default/files/news/CovidEcon1%20final.pdf
Krämer, W., W. Ploberger, and R. Alt (1988), "Testing for Structural Change in Dynamic Models", *Econometrica* 56 (6): 1355–1369.
Krantz, O. (2019), One and a Half Millennium of Economic Change in Sweden.
https://www.researchgate.net/publication/331928477
Krantz, O. (2017), Swedish GDP 1300-1560. A Tentative Estimate, Lund Papers in Economic History 152.
Krantz, O. and L. Schön (2007), *Swedish Historical National Accounts 1800-2000*, Lund: University of Lund.
Kuznets, S. (1966), *Modern Economic Growth: Rate, Structure, Spread*,
Maddison, A. (1995), *Monitoring the World Economy 1820-1991*, Paris: OECD.
Maddison, A. (2007), *Contours of the World Economy 1-2030 AD*: *Essays in Macro-Economic History*, Oxford: Oxford University Press.
Maddison Project Dataset (2018), https://www.rug.nl/ggdc/historicaldevelopment/maddison/releases/maddison-project-database-2018
Malanima, P. (2011), "The Long Decline of a Leading Economy: GDP in Central and Northern Italy, 1300–1913", *European Review of Economic History* 15 (1): 169-219.
Marczewski, J. (1960), "Some Aspects of the Economic Growth of France, 1660-1958", *Economic Development and Cultural Change* 9 (1): 369-386, reprinted in F. Crouzet (ed.), *The Economic Development of France since 1870*, 2 vols., Aldershot: Edward Elgar, I, pp. 165-182.
Milanovic, B. (2016), *Global Inequality: A New Approach for the Age of Globalization*, Cambridge, MA: Belknap Press of Harvard University Press
Mills, T.C. (2016), "Trends, Cycles, and Structural Breaks in Cliometrics", in C. Diebolt and M. Haupert (eds.), *Handbook of Cliometrics*, Berlin-Heidelberg: Springer, pp. 509-534.
Moor, T. de and J.L. van Zanden (2010), "Girl Power: The European Marriage Pattern and Labour Markets in the North Sea Area Region in the Late Medieval and Early Modern Period", *Economic History Review* 63 (1): 1-33.
Morrisson, C. (2007), "La production française au XVIIIe siècle: stagnation ou croissance?" *Revue Européenne des Sciences Sociales* 45(137): 153-165. http://journals.openedition.org/ress/224
North, D.C. and B. Weingast (1989), "Constitutions and Commitment: The Evolution of Institutions Governing Public Choice in Seventeenth-Century England", *Journal of Economic History* 49 (4): 803-832.
O'Brien, P.K. (2018), "The Costs and Benefits of Mercantilist Warfare", *Financial History Review* 25(1): 97-112.
Palma, N. and J. Reis (2019), "From Convergence to Divergence: Portuguese Economic Growth, 1527–1850", *Journal of Economic History* 79 (2): 477-506.
Pamuk, S. (2007), "The Black Death and the Origins of the 'Great Divergence' across Europe, 1300-1600", *European Review of Economic History* 11 (3): 289-317.

Parker, G. (1975), "War and Economic Change: The Economic Costs of the Dutch Revolt", in J.M. Winter (ed.), *War and Economic Development*, Cambridge: Cambridge University Press, pp. 49-71.

Perron, P. (1989), "The Great Crash, the Oil Price Shock, and the Unit Root Hypothesis", *Econometrica* 57 (6): 1361-1401.

Perron, P. (1990); "Testing for a Unit Root in a Time Series with a Changing Mean", *Journal of Business and Economic Statistics* 8 (2): 153-162.

Perron, P. (1997), "Further Evidence on Breaking Trend Functions in Macroeconomic Variables", *Journal of Econometrics* 80: 355–385.

Perron, P. (2006).,"Dealing with Structural Breaks", in T.C. Mills and K.D. Patterson (eds.) *Palgrave Handbook of Econometric*s I. *Econometric Theory*, Basingstoke: Palgrave Macmillan, pp. 278-352.

Phillips, P.C.B. and Perron, P. (1988), Testing for a unit root in time series regression, *Biometrika*, 75(2), 335–346

Pleijt, A.M. de and J.L. van Zanden (2016), "Accounting for the "Little Divergence": What Drove Economic Growth in Pre-industrial Europe, 1300-1800?", *European Review of Economic History* 20: 387-409.

Pleijt, A.M. de and J.L. van Zanden (2019), "Preindustrial Economic Growth, ca 1270-1820", in C. Diebolt and M. Haupert (eds.), *Handbook of Cliometrics*, Springer Cham, pp. 423-438. https://link.springer.com/referenceworkentry/10.1007%2F978-3-030-00181-0_63

Pfister, U. (2017)," Germany: A Positive Institutional Shock", in P.K. O'Brien (ed.), *Economic Outcomes that Flowed from the Revolutionary and Napoleonic Wars, 1793-1815* (forthcoming)

Pomeranz, K. (2000), *The Great Divergence. China, Europe, and the Making of the Modern World Economy*, Princeton: Princeton University Press.

Prados de la Escosura, L. (2000)," International comparisons of real output, 1820-1990: An Alternative Data Set", *Explorations in Economic History* 37 (1): 1-41.

Prados de la Escosura, L. (2017), *Spanish Economic Growth, 1850-2015*, London: Palgrave Macmillan.

Prados de la Escosura, L. and C. Santiago-Caballero (2018), The Napoleonic Wars: A Watershed in Spanish History?, EHES Working Papers in Economic History 130.

Prados de la Escosura, Álvarez-Nogal, and Santiago-Caballero (2020), Growth Recurring in Preindustrial Spain: Half A Millennium Perspective, CEPR Discussion Papers 14479.

Ridolfi, L. (2016), The French Economy in the Longue Durée. A Study on Real Wages, Working Days and Economic Performance from Louis IX to the Revolution (1250-1789), Unpublished Ph.D. Dissertation, IMT School of Advanced Studies, Lucca.

Robinson, P. M. (1995), "Gaussian Semiparametric Estimation of Long Range Dependence", *Annals of Statistics* 23 (5): 1630-1661.

Roosen, J. and D.R. Curtis (2018), "Dangers of Noncritical Use of Historical Plague Data", *Emerging Infectious Diseases* 24 (1): 103-110. https://wwwnc.cdc.gov/eid/article/24/1/17-0477_article

Scheidel, W. (2017), *The Great Leveler. Violence and the History of Inequality from the Stone Age to the Twenty-first Century*, Princeton: Princeton University Press.

Schön. L. and O. Krantz (2012), "The Swedish Economy in the Early Modern Period:

Constructing Historical National Accounts", *European Review of Economic History* 16: 529-549.
Shimotsu, K. and P.C. Phillips (2005), "Exact Local Whittle Estimation of Fractional Integration", *Annals of Statistics* 33(4): 1890-1933.
Shimotsu, K. (2010), "Exact Local Whittle Estimation of Fractional Integration with Unknown Mean and Time Trend", *Econometric Theory* 26 (2): 501-540.
Toutain, J.C. (1997), "Le produit intérieur de la France de 1789 à 1994 », *Economies et Sociétés, XXXI. Série AF Histoire quantitative de l'Economie francaise* (Cahiers de l'ISMEA).
Velasco, C. (1999a), "Gaussian Semiparametric Estimation of Non-stationary Time Series*", Journal of Time Series Analysis* 20 (1): 87-127.
Velasco, C. (1999b), "Non-stationary Log-periodogram Regression", *Journal of Econometrics* 91 (2): 325-371.
Velasco, C. (2006), "Semiparametric Estimation of Long-Memory Models", in K. Patterson and T.C. Mills (eds.),*Palgrave Handbook of Econometrics*, I. *Econometric Theory*, London: Palgrave MacMillan, pp. 353-395.
Voigtländer, N. and H.-J. Voth (2013a), "Gifts of Mars: Warfare and Europe's Early Rise to Riches", *Journal of Economic Perspectives* 27 (4): 165-186.
Voigtländer, N. and H.-J. Voth (2013b), "The Three Horsemen of Riches: Plague, War, and Urbanization in Early Modern Europe", *Review of Economic Studies* 80: 774-811.
Zanden, J.L., E. Buringh, and M. Bosker (2012), "The Rise and Decline of European Parliaments, 1188-1789", *Economic History Review* 65 (3): 835-861.
Zanden, J.L. van and B. Van Leeuwen (2012), "Persistent but Not Consistent: the Growth of National Income in Holland 1347–1807", *Explorations in Economic History* 49: 119-130.
Zeileis, A., C. Kleiber, W. Krämer, and K. Hornik (2003), "Testing and Dating of Structural Changes in Practice", *Computational Statistics and Data Analysis* 44 (1-2): 109-123
Zivot, E. and D.W.K. Andrews (1992), "Further Evidence on the Great Crash, the Oil Price Shock, and the Unit Root Hypothesis", *Journal of Business and Economic Statistics* 10: 251–270

Appendix A. Technical sections

A.1 Long memory

It is not easy to track the origin of long memory in literature. However, the initial efforts of long-range dependence in economics date back to the simultaneous studies of Granger and Joyeux (1980) and Hosking (1981), who introduced the autoregressive fractionally integrated moving average model (ARFIMA models). This type of processes have long lasting autocorrelations that decay hyperbolically compared with the geometric decay of ARMA processes. However, there is no a simple way to define what long memory specifically means. See Beran et. al (2016) for a review of long memory definitions.

The long memory concept is defined in a covariance sense as follows:

Definition 1. Long Memory.

Let y_t *be a stationary time series with autocovariance function* $\gamma_y(k)$*, and let* $d \in (0,0.5)$*, then* y_t *has long memory in the covariance sense if*

$$\gamma_y(k) \equiv \mathrm{cov}(y_t, y_{t+k}) \approx C_y k^{2d-1}, \quad \text{as } k \to \infty \tag{A.1}$$

with C_y *a constant.*

Equation (A.1) indicates that the autocovariance function $\gamma_y(k)$ decays to zero as a power function of the lag k, where the decay rate is determined by the long memory parameter d. It is required that $d < 0.5$ for covariance stationarity. Definition 1 describes the long memory concept in the time domain sense; nevertheless, it is also possible to write another alternative (and interchangeably) definition of long memory in the spectral sense, where the long-range dependence is reflected in the spectral density of the time series. A formal presentation of this definition as well as the treatment of the spectral density is beyond the scope of this paper, however it is important to point out that semiparametric methods of estimating d, that employ the frequency domain, are mostly used in practice.

Thus, we say that y_t exhibits long memory behaviour with covariance stationarity if the fractional memory parameter $d \in (0,0.5)$. Sometimes, after (over) differencing y_t, it is possible to find negative values on d, however as long as $d > -0.5$, the series remains invertible. Furthermore, the memory parameter can also go beyond the stationarity border $d = 0.5$. Such cases are very useful to characterize the long-run behaviour of nonstationary time series by means of the class of (fractionally) integrated I(d) processes, that nest the original I(0) and I(1) cases. We explain below the enigmatic word "fractional".

The concept refers to the application of the specific filter $(1-\mathrm{L})^{d}$ in terms of the usual lag operator L, such that for any real d (no integer)

$$(1-\mathrm{L})^{d}=\sum_{\mathrm{j}=0}^{\infty}\psi_{\mathrm{j}}(d)\mathrm{L}^{\mathrm{j}}, \qquad \psi_{\mathrm{j}}(d)=\frac{\Gamma(\mathrm{j}-d)}{\Gamma(\mathrm{j}+1)\Gamma(-d)},\ \mathrm{j}=0,1,\dots, \tag{A.2}$$

where $\Gamma(\mathrm{z})$ is the gamma function, and $\Gamma(0)/\Gamma(0)=1$. Then, we say that $\mathrm{y_t}$ is $\mathrm{I}(d)$, that is, fractionally integrated of order d, if $(1-\mathrm{L})^{d}\,\mathrm{y_t}\sim\mathrm{I}(0)$.

Definition 1 basically extents the common stationary ARMA model to the ARFIMA models aforementioned. We explain the model below.

The fractionally integrated process $\mathrm{y_t}$ is defined as follows:

$$(1-\mathrm{L})^{d}(\mathrm{y_t}-\mu)=\epsilon_{\mathrm{t}}, \tag{A.3}$$

where $\mathrm{y_t}$ is the time series modelled, μ is the unconditional mean of $\mathrm{y_t}$, the fractional integration parameter d is any real number (not necessary integer as in the ARIMA case), L is the usual lag operator, and ϵ_{t} is the usual white noise process. The operator $(1-\mathrm{L})^{d}$ is the fractional difference filter defined in (A.2).

There are different methods to estimate the fractional parameter d. Although it is possible to assume a parametric specification for the short memory component of $\mathrm{y_t}$, practitioners sometimes are only interested in the parameter d in definition 1. In such cases, semiparametric methods originally proposed by Geweke and Porter-Hudak (1983), rely on the periodogram of $\mathrm{y_t}$ to estimate d. In this type of estimation methods, the bandwidth (m) is a tuning parameter and defines how small or how large the vicinity to the origin is, relative to the sample size. These methods belong to a family of semiparametric estimators called Local Whittle (LW) and evaluate the periodogram of $\mathrm{y_t}$ only locally, in a vicinity of the origin, where the spectral density of $\mathrm{y_t}$ is driven only by the memory parameter d (Velasco, 2006). In this light, many different estimators have been proposed in the literature.

Robinson (1995b) introduces a Gaussian semiparametric estimate (referred as LW estimates) of d, based on the minimization of a local Whittle frequency domain log-likelihood, but only in the stationary region, that is for $d\in(-0.5\,,0.5)$. This framework is revised and extended in some other papers, see Velasco (1999a, 1999b) for the region $d \in (-1/2\ ,\ 3/4\ )$, for instance. Moreover, Shimotsu and Phillips (2005) study consistency and limiting normality beyond the unit root case and $d = 3/4$ in their procedure called Exact Local Whittle (ELW). The Two-Step Exact Local Whittle (2ELW) and the fully extended local Whittle (FELW) estimators used in this paper are sophisticated versions of the LW and ELW estimators aforementioned. For further details of the estimation methods as well as many other procedures to estimate the long memory parameter, cf. Beran et al. (2016). In Table 1, we show the memory parameters estimates of the GDP per head for our sample of seven European countries over the last seven centuries.

Table A.1. Long Memory Estimates for the Full Period of Each Country

	LW			ELW			2ELW			FELW		
Bandwidth (m=T^)	0.60	0.65	0.70	0.60	0.65	0.70	0.60	0.65	0.70	0.60	0.65	0.70
Spain	1.00	1.12	1.08	1.15	0.99	0.97	1.15	1.14	1.10	1.14	1.14	1.10
Portugal	1.02	1.06	1.01	1.13	0.96	0.93	1.13	1.07	1.02	1.13	1.07	1.02
Italy	1.07	1.09	1.00	1.21	1.04	0.99	1.21	1.10	1.02	1.21	1.10	1.02
France	1.00	1.06	1.06	1.20	0.98	0.99	1.21	1.08	1.07	1.21	1.07	1.07
Sweden	0.99	0.99	0.90	1.15	0.95	0.93	1.15	1.01	0.92	1.14	1.00	0.92
Netherlands	0.96	0.91	0.91	0.97	0.95	0.94	0.96	0.93	0.92	0.95	0.92	0.92
United Kingdom	0.99	0.97	0.96	1.10	0.98	0.98	1.10	1.01	0.99	1.08	1.00	0.98
North Sea Area	0.98	1.03	0.99	1.09	0.96	0.95	1.09	1.05	1.01	1.08	1.04	1.00

Sources: See the text.

Note: For all countries, standard deviations are 0.07, 0.06, and 005 for cases with $m = T^{0.6}$, $m = T^{0.65}$, and $m = T^{0.7}$, respectively. LW refers to Local Whittle of Robinson (1995b), ELW refers to Exact Local Whittle of Shimotsu and Phillips (2005), 2ELW refers to Two-Step Exact Local Whittle (2ELW) of Shimotsu (2010) and FELW refers to the fully extended local Whittle of Abadir et al. (2007).

A.2 Testing for structural breaks

The method proposed by Bai and Perron (1998, 2003a,b) has been widely used in different applications mostly because it can deal with multiple structural breaks in contrast with classical tests that often consider a single change or assume the timing and the type of change are known. The most important characteristic of the BP method is the assumption that the potential structural breakpoints are unknown and to determine endogenously the structural breaks dates.

The general framework of BP analysis can be described by the following multiple linear regression model with m breaks, that is $m + 1$ regimes,

$$y_t = x_t'\beta + z_t'\delta_j + u_t, \qquad t = T_{j-1} + 1, \ldots, T_j, \tag{A.4}$$

for $j = 1, \ldots, m + 1$, where y_t is the dependent variable at time t, x_t and z_t are $(p \times 1)$ and $(q \times 1)$ vector of covariates with β and $\delta_j \, (j = 1, \ldots, m + 1)$ are their corresponding vector of coefficients, and u_t is the usual disturbance at time t. Since the method treats the break points indices, $(T_1, \ldots, T_m)$, as unknown, then the goal is the joint estimation of the unknown parameters together with the break points. Note that the parameter β is not subject to shifts in equation (A.4).

The methodology is valid under fairly general assumptions (cf. Krämer, et al. 1988; and Bai, 1997). In a nutshell, assumptions are satisfied if $\{u_t\}$ is a martingale difference with u_t independent of the explanatory variables, which need to be (almost) stationary. Trending regressors are permitted, which is in line with our purposes.

The BP testing procedure allows for up to nine breaks and up to ten regressors whose coefficient are the object of the test as mentioned before. The asymptotic critical values are computed by Bai and Perron (1998) via simulations. BP methodology employs a sequential F test to infer how many shifts have the time series. The idea is that the full sample is divided into subsamples depending of a trimming parameter that defines the minimal segment size that may be given as fraction relative to the sample size. Such trimming parameter is chosen and calibrated by the practitioner.

As mentioned in the Section X, we consider the following setup,

$$y_t = \beta_{0,j} + \beta_{1,j}\, t + u_t, \qquad t = T_{j-1}, \ldots, T_j.$$

for $j = 1, \ldots, m + 1$. Then, we are concerned with testing the hypothesis that the regression coefficients remain constant, that is,

$$\text{H0: } \beta_i = \beta_0 \quad (i = 0, 1), \tag{A.5}$$

against the alternative that at least one of parameters (β_0, β_1) varies over time. The intuition is that both coefficients shift from one stable linear trend to a different one as a consequence of a particular historical event. Therefore, we have $m + 1$ regimes in which the trend is stable.

Following Bai and Perron (1998), the multiple structural changes are identified in the following manner: For each m-subsamples $(T_1, \dots, T_m)$, denoted $\{T_j\}$, the least squares estimates of $\beta_{0,j}$, and $\beta_{1,j}$ are obtained by minimizing the sum of squared residuals

$$S_T(T_1, \dots, T_m) = \sum_{j=1}^{m+1} \sum_{t=T_{i-1}+1}^{T_i} \left[y_t - \beta_{0,j} + \beta_{1,j}\, t\right]^2, \tag{A.6}$$

where S_T represents the sum of squared residuals in m-partition. Let $\hat{\beta}_0(\{T_j\})$ and $\hat{\beta}_1(\{T_j\})$ denote the resulting estimates. Next, substituting these into Equation (A.6), gives the estimated break points

$$\left(\hat{T}_1, \dots, \hat{T}_m\right) = \underset{T_1,\dots,T_m}{\operatorname{argmin}} S_T(T_1, \dots, T_m), \tag{A.7}$$

where the minimization is taken over all partitions $(T_1, \dots, T_m)$. This means that the break-points estimators are global minimizers of the objective function. The BP method efficiently solve the minimization problem by dynamic programming. Zeileis et al. (2003) implement the algorithm using the R system for statistical computing.

Appendix B. Alternative Estimates for Portugal (IPG) and France (Rinaldi original)

Table B.1 Structural Breaks, Regimes, Persistence, and Trend Growth in Portugal (IPG) and France (Ridolfi)

	Regime	Period	Duration	CI 95%	FELW	2ELW	CI 95%	Trend Growth (%)
PORTUGAL	1	1527-1575	49	(1574,1577)	0.52	0.91	(0.69,1.12)	0.43
	2	1576-1626	51	(1607,1628)	0.50	0.35	(0.14,0.56)	0.28
	3	1627-1694	68	(1692,1696)	0.50	0.41	(0.22,0.60)	0.59
	4	1695-1749	55	(1748,1750)	0.57	0.66	(0.44,0.87)	0.62
	5	1750-1799	50	(1794,1800)	0.50	0.66	(0.44,0.87)	-0.46
	6	1800-1858	59	(185651860)	0.71	0.77	(0.57,0.97)	0.27
	7	1859-1916	58	(1914,1917)	0.84	0.88	(0.68,1.08)	0.66
	8	1917-1966	50	(1965,1967)	0.83	0.98	(0.76,1.19)	2.14
	9	1967-2019	53	--	0.99	0.98	(0.77,1.18)	2.23
FRANCE	1	1280-1374	95	(1374,1377)	1.06	1.14	(0.97,1.30)	0.40
	2	1375-1547	173	(1547,1548)	1.33	1.50	(1.33,1.66)	-0.10
	3	1548-1678	131	(1677,1680)	1.08	1.11	(0.98,1.24)	0.10
	4	1679-1816	138	(1815,1817)	1.13	1.02	(0.87,1.16)	0.00
	5	1817-1916	100	(1914,1917)	0.50	0.31	(0.15,0.48)	1.30
	6	1917-2019	103	--	1.13	1.21	(1.04,1.37)	2.40

Table B.2 The *Little Divergence*: Structural Breaks, Regimes, and Trend in Portugal (IPG) and France (Ridolfi)

	REGIME	Period	Breaks at 95%	Duration	ADF	Trend(%)	PP	Trend(%)
PORTUGAL	1	1527-1574	(1573,1581)	48	divergence	--	long-run convergence*	--
	2	1575-1668	(1664,1669)	94	catching-up***	0.084***	long-run convergence***	--
	3	1669-1714	(1713,1718)	46	lagging-behind**	-0.622**	lagging-behind***	-0.547***
	4	1715-1760	(1759,1761)	46	catching-up*	0.073**	long-run convergence**	--
	5	1761-1817	(1816,1819)	57	divergence	--	divergence	--
	6	1818-1867	(1865,1868)	50	lagging-behind**	-0.888**	lagging-behind***	-0.932***
	7	1868-1913		46	divergence	--	divergence	--
FRANCE	1	1348-1435	(1432,1438)	88	lagging-behind***	-0.124***	lagging-behind***	-0.131***
	2	1436-1569	(1532,1545)	134	lagging-behind**	-0.080***	lagging-behind***	-0.093***
	3	1570-1679	(1626,1630)	110	lagging-behind***	-0.007***	lagging-behind***	-0.007***
	4	1680-1816	(1814,1816)	137	lagging-behind***	-0.063***	lagging-behind***	-0.081***
	5	1817-1913		97	catching-up**	0.110**	catching-up***	0.139***

Sources: See the text.
Notes: Estimation of trending regimes by BP methodology. ADF corresponds to Augmented Dickey Fuller tests, while PP88 is the Phillips-Perron (1988) test. Trend Growth represents slope estimates × 100. Symbols *, **, and *** denote rejection of the null hypothesis (unit root or significance of the trend) at the 10, 5, and 1% levels, respectively.

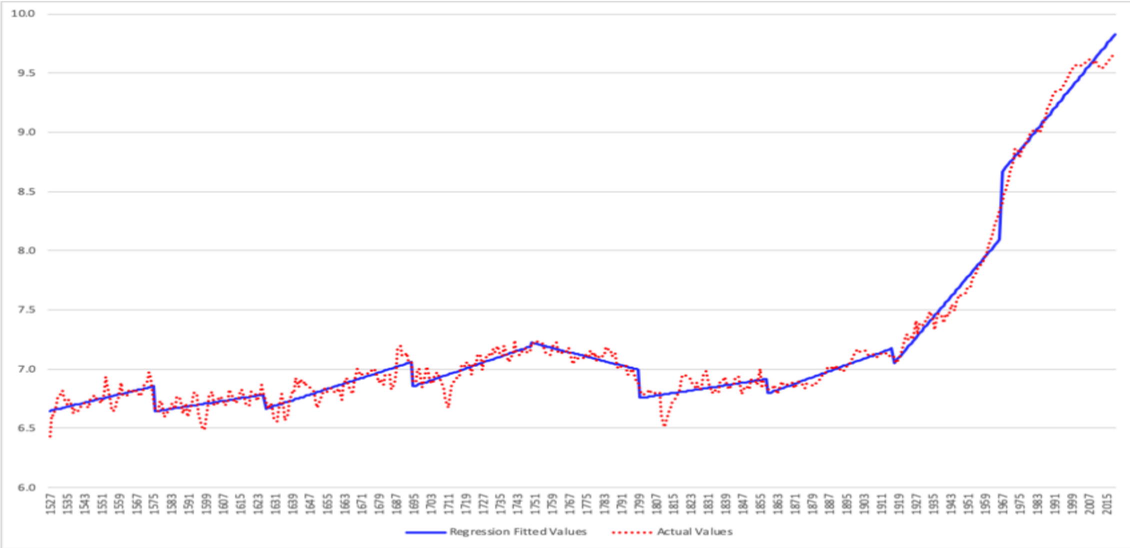

Figure B.1a. GDP per Head: Portugal (IPG), 1527-2019: Trend and Original Values (h=10)

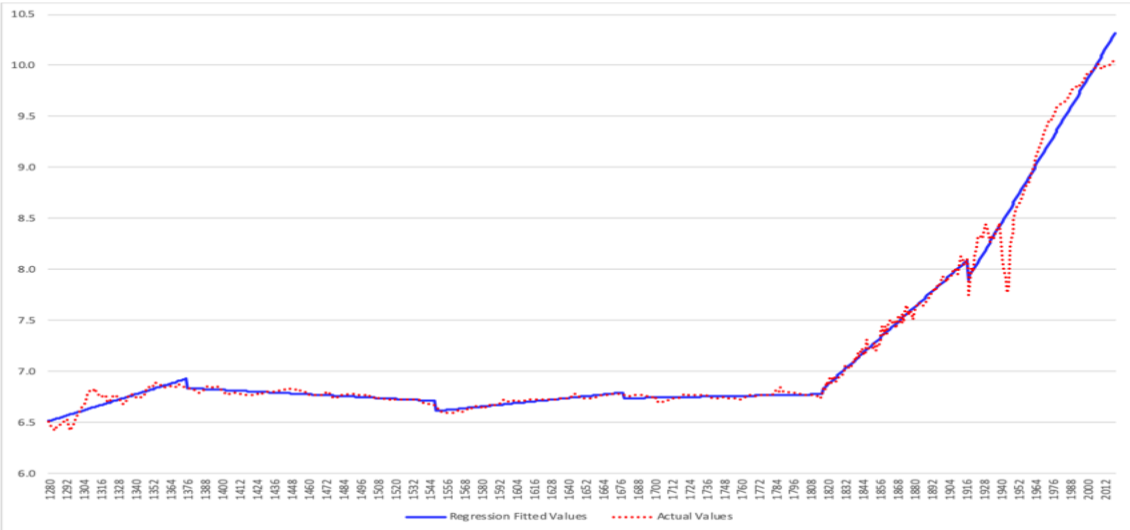

Figure B.1b. GDP per Head: France (Ridolfi original series) 1280-2019 Trend and Original Values (h=0.13)

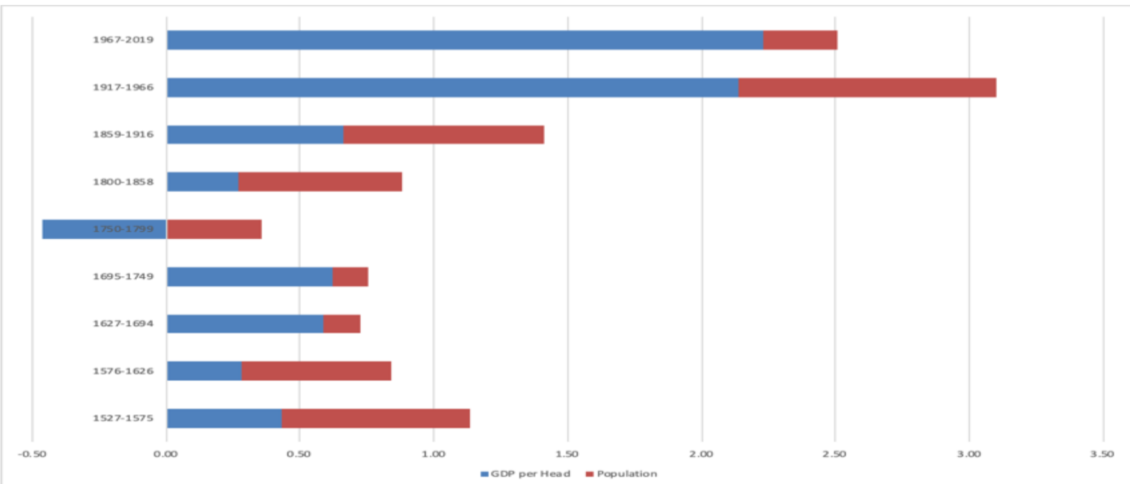

Figure B.2a. Trend Growth in GDP and its Components: Portugal (IPG), 1527-2019 (%).

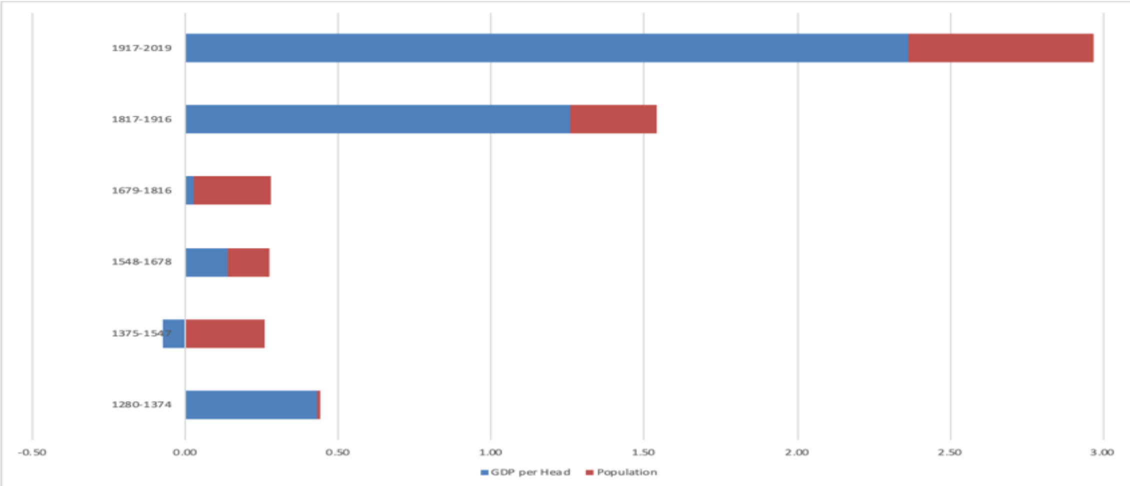

Figure B.2b. Trend Growth in GDP and its Components: France, 1280-2019 (%) (Rodolfi original series)

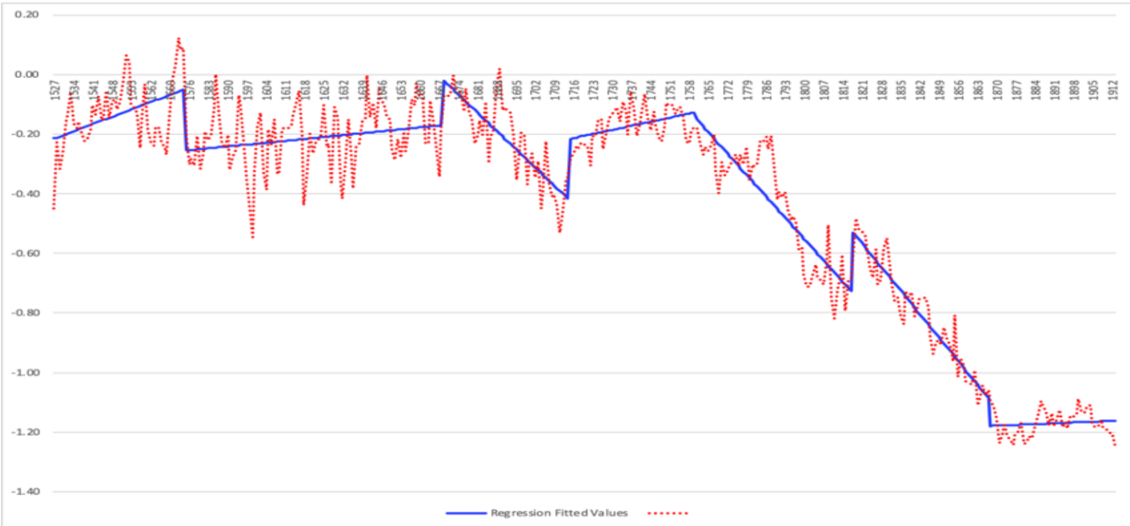

Figure B.3a. The Little Divergence: Portugal (IPG) and the North Sea Area, 1527-1913.

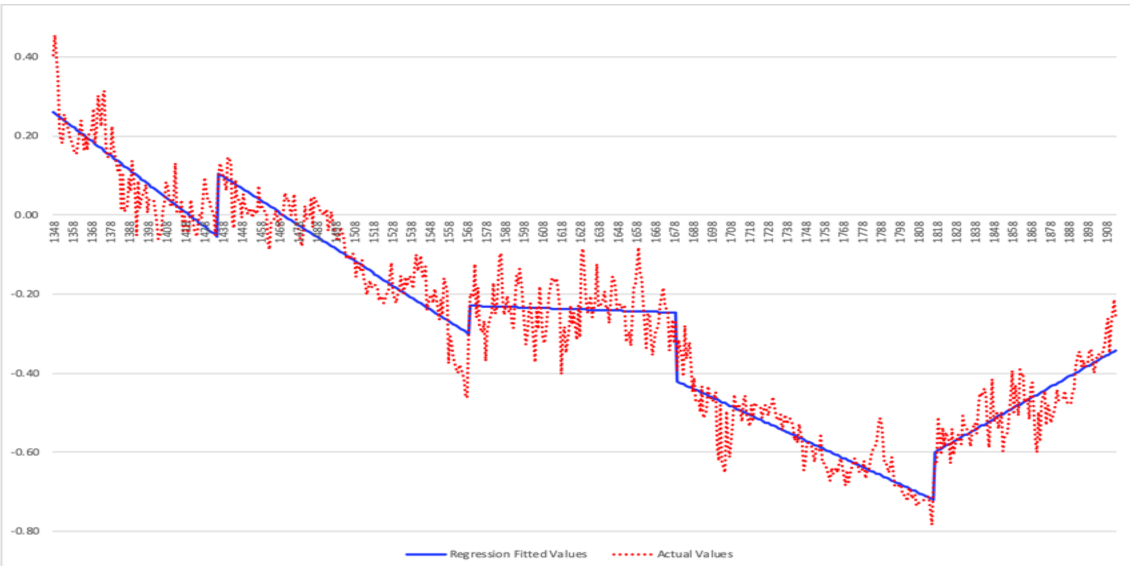

Figure B.3b. The Little Divergence: France (Ridolfi original) and the North Sea Area, 1348-1913.